PROCESSES AND FORMS OF THE YALOBUSHA RIVER SYSTEM: A DETAILED GEOMORPHIC EVALUATION

Prepared By:
Andrew Simon
USDA-Agricultural Research Service
Channel and Watershed Processes Research Unit
National Sedimentation Laboratory
Oxford, Mississippi

Prepared For:
Demonstration Erosion Control Project
U.S. Army Corps of Engineers
Vicksburg District
Vicksburg, Mississippi

July 1998

Table of Contents

Introduction 1
Geographic Scope 1
Historical Background 1
Initial Channelization Projects 2
1940 Drainage Conditions 2
1960's Channel Work 3
Hydrology 3
Specific Gage 7
Geomorphic Evaluations 7
Site Selection 7
Field Methods 12
Stage of Channel Evolution 12
Bed Conditions 26
Bank Conditions 27
Channel Conditions 27
Stage VI Stable Conditions 32
Stage V Conditions 32
Stage IV Conditions 39
Frequency and Location of Bank Failures 46
Stage III Conditions 65
Area-Gradient-Index and Historical Thalweg Elevations 68
Empirical Bed-Level Model for the Yalobusha River 68
Bed-Material Characteristics 73
Incipient Motion of Bed Material 75
Sediment Budgets and Yields 77
Shear Strength and Channel-Bank Stability 79
Shear Strength Testing 79
Bank-Stability Analysis 81
Factor of Safety Analysis for Current and Future Conditions 86
Conditions Along Lower Yalobusha River and Topashaw Creek 88
Effects of Removal of Sediment/Debris Plug 88
Conditions Middle and Upper Reaches of Yalobusha River and Topashaw Creek 99
Conditions Along Tributaries Containing a Sand Unit 99
Planform Changes 99
Summary of Geomorphic Conditions in the Yalobusha River System 103
Acknowledgments 128
References 130
Appendix 132

LIST OF ILLUSTRATIONS

1. Change in the relation between flow discharge and the percentage of time a given flow is equaled or exceeded for the Yalobusha River at Calhoun City......... 4
2. Peak discharges for the Yalobusha River at Calhoun City before and after channelization in 1967. 5
3. Frequency of peak discharges above base of 312 m^3/s (11,000 ft^3/s) for the Yalobusha River at Calhoun City. 8
4. Annual minimum stage and specific-gage elevations for recurrence interval flows of 1.005-, 1.01-, 2-, 5-, and 10-years for the Yalobusha River at Calhoun City. Note that discharge values are adjusted according to drainage area (See Table 2). 9
5. Annual minimum stage and specific-gage elevations for recurrence interval flows of 1.005-, 1.01-, 2-, 5-, and 10-years for the Topashaw Creek at Calhoun City. Note that discharge values are adjusted according to drainage area (See Table 2). 10
6. Example field form used for geomorphic evaluations. 13
7. Six-stage model of channel evolution (Simon and Hupp, 1986). 18
8. Six-stages of bank-slope development (Simon and Hupp, 1986). 19
9. Photograph taken in 1969 of transition area between channelized section and "natural" sinuous section of the Yalobusha River main stem. 28
10. Thalweg profiles of lower Yalobusha River in the vicinity of the sediment/debris plug, showing initial development in 1969, 2 years after the completion of the most recent channel work. 29
11. Time-series cross-section surveys for Yalobusha River at river kilometer 3.55 (Y-1) showing rapid deposition. 30
12. Thalweg profiles of lower Yalobusha River and Topashaw Creek showing extremely flat and even negative, local channel-gradients.................................. 31
13. Stage VI stable-slope relations. Relation in red is without 5 most downstream sites on the Yalobusha River. 33
14. Stage V stable-slope relation. 34
15. Annual minimum stage of the Yalobusha River at Calhoun City showing amount of and episodic nature of aggradation.. 40
16. Maximum bank heights along the Yalobusha River main stem for 1967 and 1997. 41
17. Maximum bank heights along Topashaw Creek for 1967 and 1997. 42
18. Channel depths of tributaries to the "lower" Yalobusha River. 43
19. Channel depths of tributaries to the "upper" Yalobusha River. 44
20. Channel depths of tributaries to Topashaw Creek with distance above the Yalobusha River, showing progression of the degradation process (A), and with distance upstream from the mouth of each stream (B)................................. 45
21. Comparison of maximum bank heights with the percentage of the reach with failing banks for Topashaw Creek. 47
22. Comparison of maximum bank heights with the percentage of the reach with failing banks for the Yalobusha River. 48

23. Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System (A-P)...................... 49
24. Area-gradient-index values for Yalobusha River, Topashaw Creek and Bear Creek, showing peak values between basin river-kilometers 24-28..................... 69
25. Comparison of area-gradient-index (AGI) values for 1967 and 1997 along the Yalobusha River main stem, (A) and AGI values for Topashaw and Bear Creeks showing synchronous peaks at river kilometers 24-28 and Topashaw AGI peak at river kilometer 15 (B)... 70
26. Yalobusha River profiles from 1967 and 1997 showing NRCS cross-section locations.. 71
27. Examples of fitting historical bed-elevation data to equation 3. 72
28. Empirical model of bed-level response for the Yalobusha River main stem derived from historical bed-elevation data fit to equation 3................................ 76
29. Frequency histograms and summary statistics of soil-mechanics data for main ste channels of the Yalobusha River and Topashaw Creek................................. 82
30. Frequency histograms and summary statistics of soil-mechanics data for tributary streams of the Yalobusha River System. 83
31. Bank-stability charts for streambanks of the Yalobusha River and Topashaw Creek (A); tributaries without a sand unit (B); and tributaries containing a sand unit (C). 85
32. Bank geometry used for F_s analysis showing pertinent forces.............................. 87
33. Bank-stability conditions for 4 m banks for the lower Yalobusha River and Topashaw Creek under 1997 conditions (A), and under future conditions assuming removal of the debris jam (B). 89
34. Bank-stability conditions for 6 m banks for the lower Yalobusha River and Topashaw Creek under 1997 conditions (A), and under future conditions assuming removal of the debris jam (B). 90
35. Bank-stability conditions for 8 m banks for the lower Yalobusha River and Topashaw Creek under 1997 conditions (A), and under future conditions assuming removal of the debris jam (B). 91
36. Bank-stability conditions for the middle and upper reaches of the Yalobusha River and Topashaw Creek. 100
37. Bank-stability conditions for tributaries of the Yalobusha River System with streambanks containing clay, silt, and sand.. 101
38. Historic channel locations of the lower Yalobusha River. 102
39. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Bear Creek.. 104
40. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Big Creek... 105
41. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Buck Creek.. 106
42. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Bull Creek.. 107
43. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Cane (Cook) Creek. 108

44. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Dry Creek (Topashaw Basin). 109
45. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Duncan Creek. 110
46. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Fair Creek. 111
47. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Huffman Creek. 112
48. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Hurricane Creek. 113
49. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Johnson Creek... 114
50. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Little Topashaw Creek. 115
51. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Meridian Creek. 116
52. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Miles Creek... 117
53. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Mud Creek. 118
54. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Naron Creek.. 119
55. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for North Topashaw Creek... 120
56. Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Splunge Creek... 121
57. Changes in top width between 1967 and 1997 along Topashaw Creek. 122
58. Changes in top width between 1967 and 1997 along the Yalobusha River. 123

LIST OF TABLES

1. Amount and type of erosion-control structures in the Yalobusha River System............6
2. Adjusted discharge values of 1.005-, 1.01-, 2-, 5-, and 10-year recurrence interval flows for the Yalobusha River and Topashaw Creek at Calhoun City. 11
3. Summary of field data collected for geomorphic evaluations. 20
4. Six-stage model of channel evolution (Simon, 1989). 25
5. Data used to develop stage VI stable-slope relation for the Yalobusha River System (equation 1) showing observed and predicted equilibrium slopes. 35
6. Predicted stable slopes for reaches currently (1997) in stage III, IV, or V using the stage VI stable-slope relation (equation 1; See Figure 13). Note that percent differences are all negative, indicating further flattening of channel gradients. 36
7. Predicted stable slopes for reaches currently (1997) in stage III, IV, or V using the modified stage VI stable-slope relation (equation 2; See Figure 13). Note that percent differences are all negative, indicating further flattening of channel gradients. 38
8. Location, size, and material type of major knickpoints in the Yalobusha River System as observed during 1997 field and aerial inspections. 66
9. Largest knickpoints in the Yalobusha River System as determined from 1997 surveys. 67
10. Regression data used to develop empirical model of bed-level response for historic cross sections on the Yalobusha River main stem (See Figure 28). 74
11. Sediment budgets for selected streams of the Yalobusha River System......................78
12. Summary of geotechnical data collected in the Yalobusha River System. 80
13. Geotechnical parameter values used to develop bank-stability charts. 81
14. Factor of safety values for a range of pore and confining pressure conditions on the Yalobusha River and Topashaw Creek (Bank height = 4 m). 92
15. Factor of safety values for a range of pore and confining pressure conditions on the Yalobusha River and Topashaw Creek (Bank height = 6 m). 93
16. Factor of safety values for a range of pore and confining pressure conditions on the Yalobusha River and Topashaw Creek (Bank height = 8 m). 94
17. Factor of safety values for a range of pore and confining pressure conditions on the Yalobusha River and Topashaw Creek (Bank height = 10 m). 95
18. Factor of safety values for a range of pore and confining pressure conditions on the tributaries with streambanks containing clay, silt, and sand (Bank height = 4 m). 96
19. Factor of safety values for a range of pore and confining pressure conditions on the tributaries with streambanks containing clay, silt, and sand (Bank height = 6 m). 97
20. Factor of safety values for a range of pore and confining pressure conditions on the tributaries with streambanks containing clay, silt, and sand (Bank height = 8 m). 98
21. Summary of channel conditions and dominant bed and bank processes for studied reaches. 124

INTRODUCTION

The potential for catastrophic flooding along downstream reaches of the Yalobusha River has dramatically increased since the early 1960's. As a consequence of channel adjustment processes related to channelization near the turn of the 20th century and in the late 1960's, upstream migrating knickpoints caused deepening of upstream reaches and tributary channels. Sufficient deepening occurred to cause significant channel widening by mass failure of channel banks. Woody vegetation growing on these channel banks was delivered to the flow when the banks failed and was been transported downstream to form a large debris jam.

Sediment eroded from the boundary of the Yalobusha River, its tributaries, and from upland areas has been deposited in downstream reaches of the Yalobusha River and Topashaw Creek, thereby reducing flow capacity. This is typical of channelized streams (Simon, 1989; 1994). The debris jams function as dams and cause higher water levels and slower flow velocities than previous. This in turn causes even greater rates of deposition, further reductions in channel capacity, and an increase in the magnitude and frequency of floods.

The erosion of channel materials from the bed and banks of tributary channels and upstream reaches of Yalobusha River and Topashaw Creek continues. Similarly, channel filling of the downstream reaches of these 2 streams further reduces channel capacity.

To assist the U.S. Army Corps of Engineers, Vicksburg District in developing a Technical Work Plan for the purpose of mitigating drainage problems along the Yalobusha River System, the Agricultural Research Service, National Sedimentation Laboratory (NSL) undertook a geomorphic evaluation of the Yalobusha River System.

GEOGRAPHIC SCOPE

The geographic scope of this study is the Yalobusha River System upstream of the sediment-debris plug. This area includes the Yalobusha River and its tributaries upstream from this point with the exception of Fourmile Creek. The Yalobusha River upstream of the Highway 8 bridge at Pyland is also not included in the study nor are Shutispear and Sabougla Creeks. However, the un-channelized reach of the Yalobusha River between Pyland and the bridge west-southwest of Thelma were assigned stages of channel evolution during an aerial reconnaissance flight.

HISTORICAL BACKGROUND

Rapid agricultural development of the region occurred in the middle 1800's. Because of the lack of proper soil conservation practices, severe erosion of upland areas resulted in the filling of stream channels, the consequent loss of channel capacity, and frequent and prolonged flooding. Areas of northern Mississippi were considered "badlands" (Lowe, 1910) because of severe sheet and gully erosion, while parts of the Yalobusha River Watershed were considered "destroyed by gullying" (Mississippi State Planning Commission, 1936). Cropland in valley bottoms was commonly buried with sand and debris eroded from upstream.

Initial Channelization Projects (1910-1920's)

To improve floodplain drainage and reduce the frequency of flooding, local drainage districts were formed throughout the region and specifically, throughout the Yalobusha River Watershed. The Yalobusha Swamp Land District No. 1 was organized about 1909 and received funding for constructing drainage improvements in 1910. A 19.3 km-long straight ditch was excavated through the Yalobusha River valley from the Calhoun -Chickasaw County line (Section 13, Township 14 south, Range 1 east), downvalley to an outlet into the sinuous channel of the river about 1.8 km downstream of State Highway 9, south of Calhoun City (southeast quarter of Section 22, Township 23 North, range 9 East) (Mississippi Board of Development, 1940a).

The Topashaw Swamp Land Drainage District was organized in 1912 and excavated a 17.7 km ditch from the Calhoun -Chickasaw County line to the Yalobusha River in Section 28, Township 23 north, Range 9 east (Mississippi Board of Development, 1940b). Topashaw Drainage District No. 2, Chickasaw County was organized in 1913 and channelized (1) 7.64 km of Topashaw Creek, and (2) 2.82 km of Little Topashaw Creek, to the Webster County line. The Topashaw Drainage District in Webster County extended the channelization into the upper watershed area (Mississippi Board of Development, 1940c).

With the exception of the downstream most reach of Topashaw Creek, the alignments of the Yalobusha River, the remainder of Topashaw Creek, and other tributaries were determined by the channelization projects undertaken by the Drainage Districts in the 1910's and 1920's. Original (1920's) channelization plans for Meridian Creek and Mud Creek are on file at the NSL.

1940 Drainage Conditions

A debris jam, formed from debris and sediment transported from upstream reaches closed the downstream end of Topashaw Creek and a reach of the Yalobusha River in the years prior to 1940 (Mississippi Board of Development, 1940b). In the late 1930's, another outlet was provided for Topashaw Creek through parts of Sections 28 and 29 of Township 23 North, Range 9 East, but by 1940, this outlet was again obstructed in some places with sediment and debris. Sedimentation had greatly reduced the capacity of the Yalobusha River in the vicinity of Calhoun City by 1940 because of (1) the heavy loads of sediment emanating from tributaries draining the north part of the basin, and (2) the filling of the lower end of Topashaw Creek.

The upstream reaches of Topashaw Creek and Yalobusha River had apparently eroded to sufficient size as to not require further enlargement in the 1940's. Reaches of Topashaw Creek, Chickasaw County were as much as much as 43 m wide and 7.6 m deep (Mississippi Board of Development, 1940c). It was, however, recommended that the downstream ends of both streams be deepened and widened to improve drainage in the area around Calhoun City. All obstructions to flow such as fences, channel bars, and trees were to be removed. It is unknown as to whether the recommendations made by the Mississippi Board of Development were enacted in the 1940's or 1950's.

1960's Channel Work

A comprehensive watershed work plan was devised and implemented by the Soil Conservation Service in the late 1960's. This plan provided for the clearing, dredging, straightening, and widening of the Yalobusha River and many of its tributaries. It also provided for the construction of various types of erosion-control structures. The most common of these structures were overfall pipes, constructed to prevent the formation and advancement of gullies into fields adjacent to the stream channels.

The Yalobusha River and Topashaw Creek were cleared and dredged from a point 850 m downstream of Shutispear Creek, upstream to the Calhoun-Chickasaw County line. The Yalobusha River was dredged to a gradient of 0.0005 with top widths ranging from 58 m at the downstream end of the channel work to 22 m at the upstream end. Topashaw Creek was constructed at a gradient of 0.00075 with top widths ranging from 27 to 38 m. In addition, the following tributary streams were cleared and or dredged throughout most of their length in Calhoun County; Bear, Big, Cane (Cook), Huffman, and Hurricane Creeks. Other tributaries had clearing, dredging, and realigning only in their downstream ends. These were Duncan, Meridian, Miles, and Splunge Creeks, as well as numerous side laterals and ditches.

During this period of channel clearing and enlargement, the upstream end of Grenada Lake was dredged (D. Gober, 1997, U.S. Army Corps of Engineers, personal commun.). Construction of additional erosion-control structures took place in the late 1960's, through the 1980's. We have been able to account for 459 structures in the Yalobusha River System. The type and location of these structures are summarized in Table 1. A complete list of structures is available from the NSL upon request.

HYDROLOGY

The U.S. Geological Survey (USGS) operates gaging stations at the Highway 9 bridge crossings of the Yalobusha River and Topashaw Creek. Flow data from these stations are combined and reported as "Yalobusha River at Calhoun City." Mean-daily discharge data from these gaging stations have been used to analyze changes in flow regime. The data set was split into 2 periods, 1951-1967 and 1968-1996. These periods represent the flow characteristics before and after the most recent channel-dredging program in 1967. As expected, the percent of time a given flow is equaled or exceeded increased for the period following the channel work (Figure 1). Similarly, for a given flow exceedance probability, the discharge that could be expected to occur also increased. For example the flow that can be expected to be equaled or exceeded 50% of the time increased from 0.50 to 1.66 m^3/s, a three-fold increase. This increase was not as significant at higher flows. The flow that is equaled or exceeded 5% of the time increased only 20%, to 62.1 m^3/s. This indicates that the channel work did indeed increase flow capacity relative to the poor drainage conditions that existed previously.

Perhaps a better measure of the change in hydrology due to the 1967 channel work is the magnitude and frequency of peak discharges. A base discharge is selected for a given gaging station by the USGS as one that is exceeded 2-3 times per year. A base discharge of 170 m^3/s was used initially but had to be increased to 312 m^3/s because of the increased frequency of peak discharges greater than the initial base. Peak discharges from 1951 to 1994 are shown in Figure 2. The general increased magnitude of peak flows for the period 1968-1994 can be

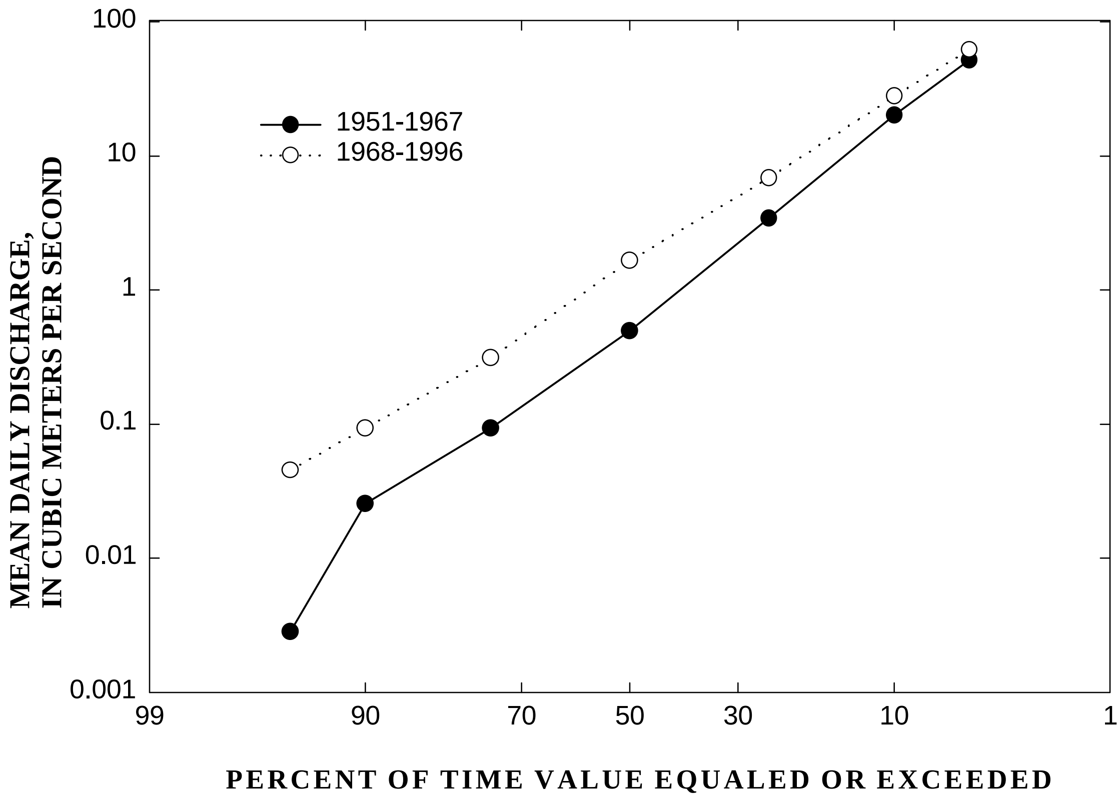


Figure 1 -- Change in the relation between flow disharge and the percentage of time a given flow is equaled or exceeded for the Yalobusha River at Calhoun City.

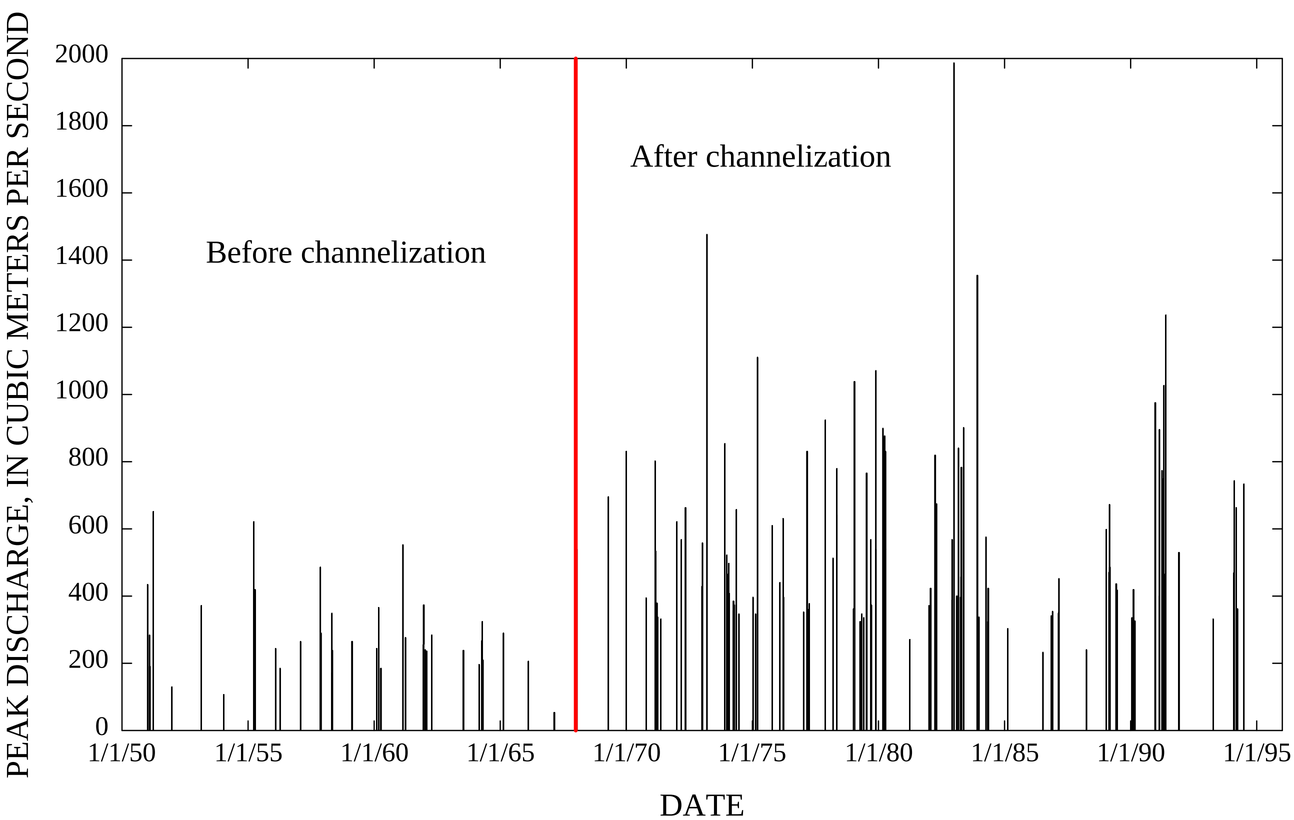


Figure 2--Peak discharges for the Yalobusha River at Calhoun City before and after channelization in 1967.

Table 1—Summary of types and location of erosion-control structures in the Yalobusha River System

Bear Creek	
Box Inlet	13
Dam	0
Drop Inlet	10
Drop Inlet and Grade Control Dam	0
Grade Control Dam	2
Hooded Dam	0
Hooded Inlet	0
Hooded Pipe	0
Overfall	19
Total Structures	44

Big Creek	
Box Inlet	33
Dam	0
Drop Inlet	0
Drop Inlet and Grade Control Dam	0
Grade Control Dam	0
Hooded Dam	0
Hooded Inlet	0
Hooded Pipe	0
Overfall	0
Total Structures	33

Buck Creek	
Box Inlet	
Dam	
Drop Inlet	
Drop Inlet and Grade Control Dam	
Grade Control Dam	1
Hooded Dam	
Hooded Inlet	
Hooded Pipe	
Overfall	
Total Structures	1

Buck Creek	
Box Inlet	
Dam	
Drop Inlet	
Drop Inlet and Grade Control Dam	
Grade Control Dam	1
Hooded Dam	
Hooded Inlet	
Hooded Pipe	
Overfall	
Total Structures	1

Cane (Cook) Creek	
Box Inlet	
Dam	
Drop Inlet	
Drop Inlet and Grade Control Dam	
Grade Control Dam	
Hooded Dam	
Hooded Inlet	
Hooded Pipe	
Overfall	40
Total Structures	40

Cowpen Creek	
Box Inlet	
Dam	
Drop Inlet	
Drop Inlet and Grade Control Dam	
Grade Control Dam	1
Hooded Dam	
Hooded Inlet	
Hooded Pipe	
Overfall	
Total Structures	1

Duncan Creek	
Box Inlet	
Dam	
Drop Inlet	
Drop Inlet and Grade Control Dam	
Grade Control Dam	
Hooded Dam	
Hooded Inlet	
Hooded Pipe	
Overfall	5
Total Structures	5

Huffman	
Box Inlet	
Dam	
Drop Inlet	
Drop Inlet and Grade Control Dam	
Grade Control Dam	1
Hooded Dam	
Hooded Inlet	
Hooded Pipe	
Overfall	27
Total Structures	28

Hurricane Creek	
Box Inlet	
Dam	
Drop Inlet	
Drop Inlet and Grade Control Dam	
Grade Control Dam	1
Hooded Dam	
Hooded Inlet	
Hooded Pipe	
Overfall	48
Total Structures	49

Meridian Creek	
Box Inlet	
Dam	
Drop Inlet	
Drop Inlet and Grade Control Dam	
Grade Control Dam	1
Hooded Dam	
Hooded Inlet	
Hooded Pipe	
Overfall	2
Total Structures	3

Miles Creek	
Box Inlet	
Dam	
Drop Inlet	
Drop Inlet and Grade Control Dam	
Grade Control Dam	
Hooded Dam	
Hooded Inlet	
Hooded Pipe	
Overfall	13
Total Structures	13

Splunge Creek	
Box Inlet	
Dam	
Drop Inlet	
Drop Inlet and Grade Control Dam	
Grade Control Dam	
Hooded Dam	
Hooded Inlet	
Hooded Pipe	
Overfall	20
Total Structures	20

Topashaw Canal	
Box Inlet	
Dam	
Drop Inlet	1
Drop Inlet and Grade Control Dam	1
Grade Control Dam	3
Hooded Dam	
Hooded Inlet	
Hooded Pipe	
Overfall	29
Total Structures	34

Topashaw Creek	
Box Inlet	5
Dam	3
Drop Inlet	13
Drop Inlet and Grade Control Dam	10
Grade Control Dam	4
Hooded Dam	
Hooded Inlet	30
Hooded Pipe	5
Overfall	11
Total Structures	81

Upper Topashaw	
Box Inlet	
Dam	
Drop Inlet	1
Drop Inlet and Grade Control Dam	19
Grade Control Dam	
Hooded Dam	6
Hooded Inlet	
Hooded Pipe	
Hooded Pipe Dam	2
Overfall	
Total Structures	28

Yalobusha	
Box Inlet	
Dam	
Drop Inlet	
Drop Inlet and Grade Control Dam	
Grade Control Dam	1
Hooded Dam	
Hooded Inlet	12
Hooded Pipe	1
Hooded Pipe Dam	
Overfall	50
Total Structures	64

Yalobusha River Canal	
Box Inlet	
Dam	
Drop Inlet	3
Drop Inlet and Grade Control Dam	10
Grade Control Dam	1
Hooded Dam	
Hooded Inlet	
Hooded Pipe	
Hooded Pipe Dam	
Overfall	
Total Structures	14

Yalobusha River and Topashaw Creek	
Overfall	1

Total Structures in the Yalobusha River System	459

clearly seen. The frequency of peak flows increased from an average of 0.65 to 3.96 for the periods before and after the 1967 channel work (Figure 3).

The discharge peak of record occurred in December 1982 (about 1,970 m^3/s) and the 3rd greatest discharge occurred only 12 months later in December 1983 (1,350 m^3/s). Other peaks, which effected channel response since the 1967 channel work were the 1973 peak of about 1,480 m^3/s, and the 1991 peak flow of about 1,240 m^3/s. These periods and those with a large number of even moderate peak discharges were probably times of significant channel adjustments.

Specific Gage

The elevation of the water surface for a range of discharges was plotted against time to determine changes in flooding characteristics in the vicinity of the Calhoun City gages. Flows with the following recurrence intervals were analyzed; 1.005-, 1.01-, 2-, 5-, and 10-year. These discharges were determined by the U.S. Geological Survey for post-construction conditions for combined flows of Topashaw Creek and the Yalobusha River such that they represent the flow at their confluence. To analyze the specific-gage elevations for each stream individually, the discharge values for each flow were adjusted according to the relative drainage area contributions (76.3% for the Yalobusha River and 23.7% for Topashaw Creek). This is an acceptable method when dealing with long-term flow relations. Adjusted discharge values are shown in Table 2. Figures 4 and 5 show specific-gage elevations for the Yalobusha River and Topashaw Creek at Calhoun City. The flood plain elevation in the vicinity of the gage is included for comparison purposes. Note that the Yalobusha River inundates the flood plain at a discharge intermediate between the 1.01- and 2-year flows. Results of the specific-gage analysis show, however, that the elevation of all flows is lower than prior to the 1967 channel work.

GEOMORPHIC EVALUATIONS

To evaluate the appropriateness, application, and location of potential erosion-control structures and mitigation strategies, it is essential to have a complete understanding of the channel system. To accomplish this, the spatial distribution of active channel processes and forms must be determined and placed in an historical context. This provides insight into how past disturbances and channel adjustments have led to current channel conditions, and how these current processes and forms can be used to estimate future channel processes and forms. To determine active channel processes and forms, geomorphic evaluations were undertaken by helicopter and by direct field inspection and sampling. Flights were taken on February 19, 27, and on April 1, 1997.

Site Selection

Sites were initially selected for evaluation that would be easily identifiable from the air during reconnaissance. The majority of these sites were, therefore, at bridges although some were also at stream confluences or at sharp bends. Field evaluation of geomorphic conditions did not take place at bridge sites but at a distance of at least 6-20 channel widths away from the structure, usually, upstream. Because of the short time frame involved to complete this project,

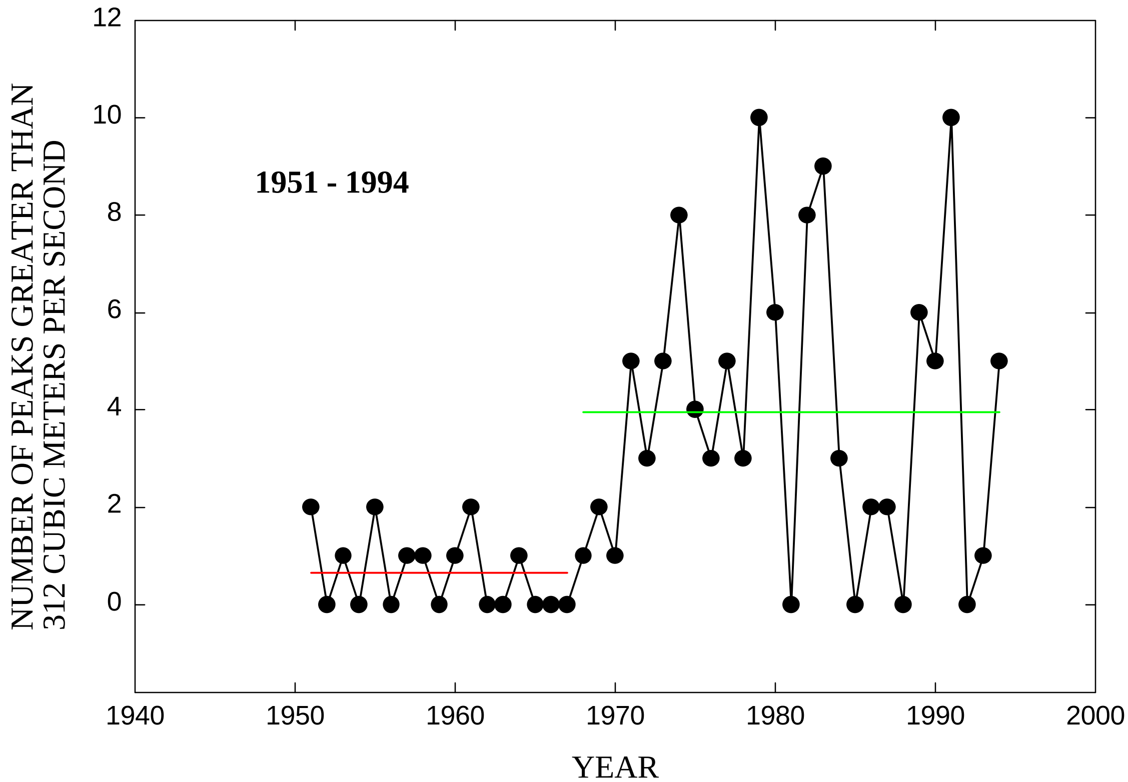


Figure 3--Frequency of peak discharges above base of 312 m^3/s (11,000 ft^3/s) for the Yalobusha River at Calhoun City. Note the increased number of peaks after the channelization in 1967.

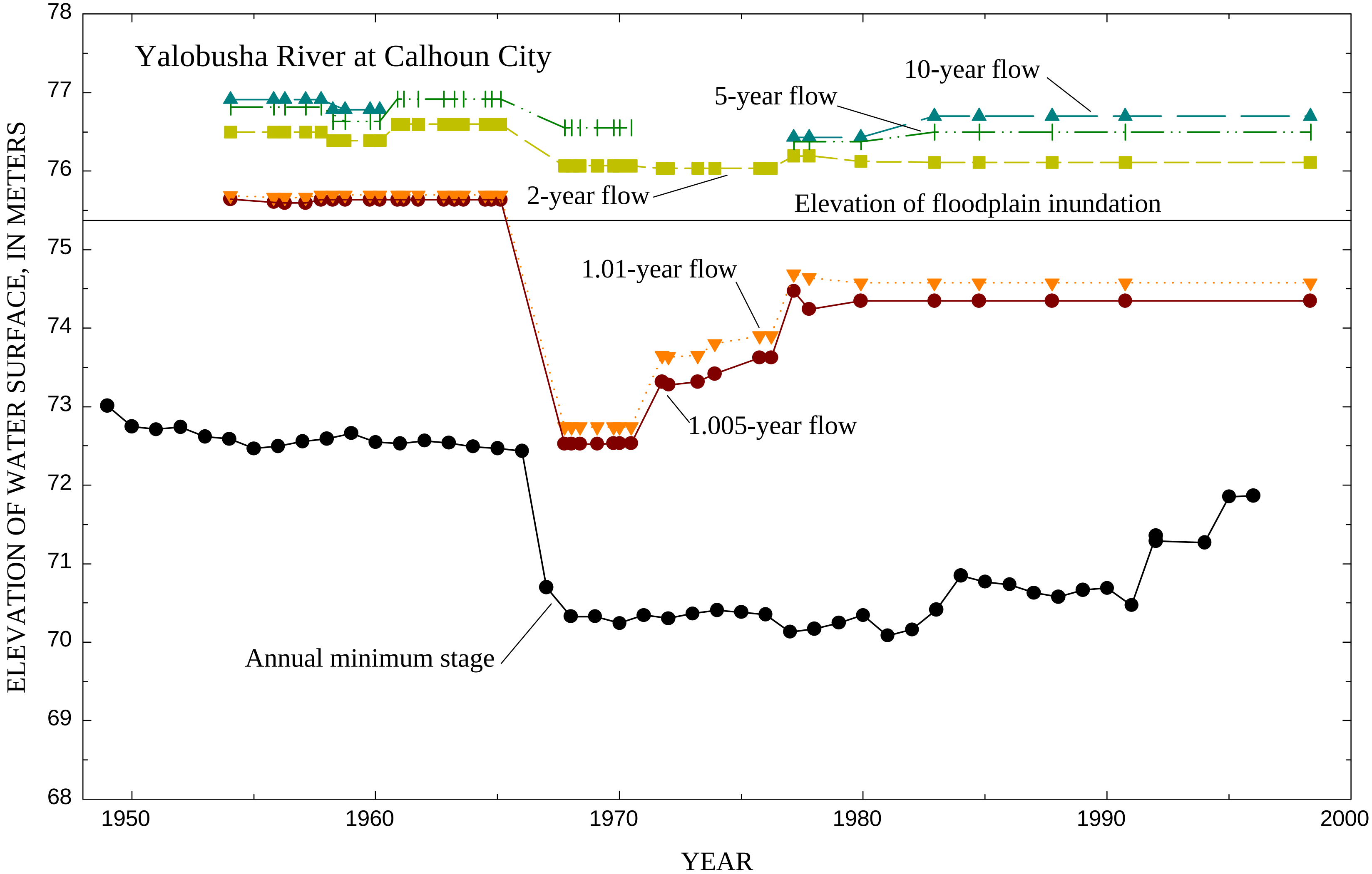


Figure 4--Annual minimum stage and specific-gage elevations for recurrence interval flows of 1.005-, 1.01-, 2-, 5-, and 10-years for the Yalobusha River at Calhoun City. Note that discharge values are adjusted according to drainage area (See Table 2).

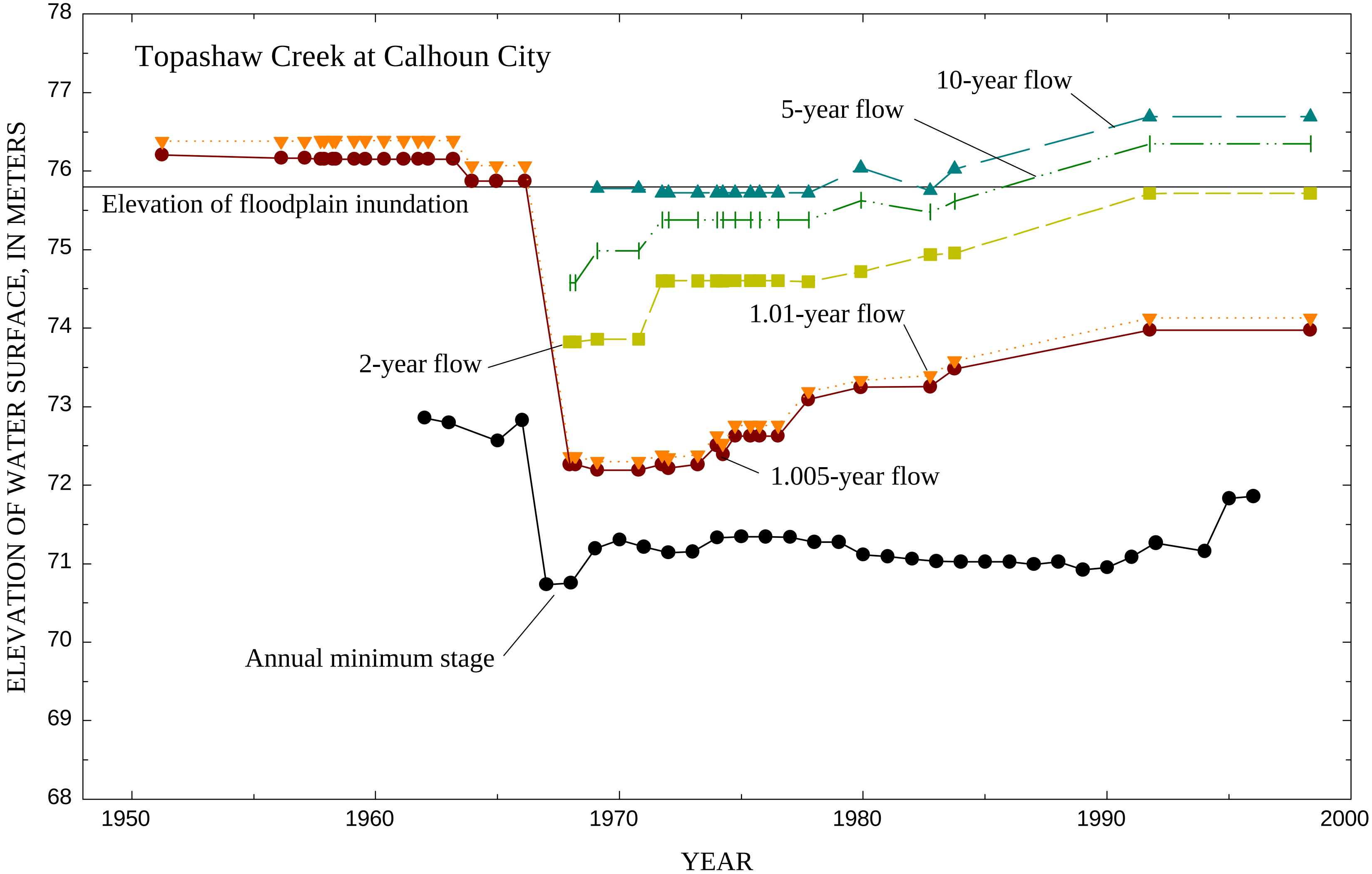


Figure 5--Annual minimum stage and specific-gage elevations for recurrence interval flows of 1.005-, 1.01-, 2-, 5-, and 10-years for the Topashaw Creek at Calhoun City. Note that discharge values are adjusted according to drainage area (See Table 2).

Table 2 - Adjusted discharge values of 1.005-,1.01-,2-,5-, and 10-year recurrence interval flows for the Yalobusha River and Topashaw Creek at Calhoun City.

Specific Gauge Height Data
Yalobusha River
USGS Station ID 0728200

Flow Event	1.005 Year	1.01 Year	2 Year	5 Year	10 Year
Q (ft^3/s)	3495	4197	19380	31283	39676
Q (m^3/s)	98.95	118.8	548.8	885.8	1123

Specific Gauge Height Data
Topashaw Creek
USGS Station ID 07282100

Flow Event	1.005 Year	1.01 Year	2 Year	5 Year	10 Year
Q (ft^3/s)	1085	1304	6020	9717	12324
Q (m^3/s)	30.74	36.9	170.5	275.2	349.0

Combined Specific Gauge Height Data

Flow Event	1.005 Year	1.01 Year	2 Year	5 Year	10 Year
Q (ft^3/s)	4580	5500	25400	41000	52000
Q (m^3/s)	129.69	155.7	719.2	1161	1472

the entire length of the study streams could not be walked and evaluated. The 140 sites that were initially selected were augmented by about 50 additional sites in transition zones and in critically unstable areas that had been identified during the initial evaluation effort. The locations of visited sites are shown in Plate 1.

Twenty-one sites were selected for geotechnical testing of bank materials. These sites coincided with evaluation sites and were selected such that the sites were (1) representative of bank materials along the main stem reaches of the Yalobusha River, Topashaw Creek, and major tributaries, (2) provided a good geographical distribution, and (3) were accessible by field crews. Three additional sites were tested and sampled during December 1997 to obtain geotechnical information from some of the clay materials found at depth. Erodibility tests were also conducted in April 1998 at 5 sites comprising clay beds.

River kilometer stationing for a given stream in this report refers to the distance above the mouth of the stream, with the exception of the Yalobusha River. Stationing for the Yalobusha River is referenced to a 0+000 point, located at the abandoned bridge in the sediment/debris plug.

Field Methods

Geomorphic evaluations generally involve assessment of diagnostic criteria about channel processes and include information about the resistance of the channel bed and banks to erosion, active channel processes, presence or absence of geomorphic surfaces, presence of knickpoints, and the state of woody riparian vegetation. An example field form specifically designed for this study is shown in Figure 6. A summary of specific data collected during the field reconnaissance phase of the study is shown in Table 3. One of the most important criteria obtained during both the field and airborne evaluations is the stage of channel evolution.

Stage of Channel Evolution

Researchers in fluvial geomorphology have noted that alluvial channels in different environments, destabilized by different natural and human-induced disturbances, pass through a sequence of channel forms with time (Elliot, 1979; Schumm et al., 1984; Simon and Hupp, 1986; Simon, 1989). These systematic temporal adjustments are collectively termed "channel evolution" and permit interpretation of past and present channel processes, and prediction of future channel processes. One of these schemes is the 5-stage channel evolution model of Schumm et al., (1984) which was developed from morphometric data acquired on Oaklimiter Creek, northern Mississippi. Another channel evolution model was developed independently by the U.S. Geological Survey at the same time from data collected north of the Mississippi-Tennessee stateline from a 27,500 km^2 area of West Tennessee (Simon and Hupp, 1986; Simon, 1989; 1994; Figure 7; Table 4). The West Tennessee model has 6 stages, is based on shifts in dominant adjustment processes, and is associated with a model of bank-slope development (Figure 8). Differences in the Schumm et al., (1984) model and the Simon and Hupp (1986) model are:

(1) Stage II of the Simon and Hupp (1986) model represents the constructed/disturbed state and can be considered as an almost instantaneous condition prior to adjustment; more importantly,

Figure 6--Example field form used for geomorphic evaluations.

YALOBUSHA RIVER STREAM-EVALUATION DATA SHEET

Index Variables:

Date: 3/12/97 Start Time: 1325 End Time: 1500 Personnel: KP, HS, JH

Stream: Bear Ck. Station ARS B1A NRCS # 19 T-19 @ 450' u/s of br. X-Section ____ Sub-Watershed: Topashaw

General Description:

Flow: medium
(high, medium, low)

Flow Depth (@ center, in m): 0.3

Flow type: p & r
(none, smooth, pool & riffle, run, rapid-tumbling)

Perrcent Pool: 50%; Percent Riffle 50%

Bankfull Indicator: berm; ____; ____
(none-incised, active floodplain, berm, woody vegetation, bar tops)

Floodplain Land Use: Left row Right row
(urban, forest, pasture, row crop)

Structure? Y Type @ 400' DS, bridge
(Yes, No) (bridge, grade control, bank)

Planform: mildly sinuous
(straight, mildly sinuous, meandering, tortuous, braided)

Bank Impact point: R; 350' US of bridge BL
(Left, right) (Distance; in m) (U/S or D/S)

Channel-Bed Description:

Dominant bed-material type: CL
(gravel=GP; sand=SP; silt=ML; clay=CL; bedrock=BR)

Bed controls: cohesive; ____
(none; bedrock; cohesive materials; armored; structure; rip-rap)

Bed-material samples: ✓; ✓; ✓ (Check all appropriate)
(Left) (Middle) (Right)

Bed-material type: CL; CL; CL
(Left) (Middle) (Right)

Knickpoint present? Y; Height: 0.3 Material: CL Samples: —; —; ____
(Yes; No) (in m) (GP, SP, ML, CL, BR) (pinhole) (density) (P.S.)

Bed width: 4.5 - method: T Berm width: 8.6 - method: T Top-bank width: 23 - method: R
(Method: tape=T; rangefinder=R; acoustic device=A; pace=P)

Planform Sketch:

lots of secondary failures of accreted and [illegible]

Figure 6--Example field form used for geomorphic evaluations.

Bank Description:

de (L; R); R Reach Type; O Stage of Evolution; V % Failing; 60 % Depositional; 60
(I=inside; O=outside; S= straight) (excluding bars)

pect (degrees); 200° Percent Woody Cover; 60% Percent Herbaceous; 70% Type; Kudzu US Grass

rfaces / Angles VF ✓/52°; UB ✓/39°; SL —/—; DS ✓/ (truncated); CS/Bar —/—; CB ✓/56°;

Slope-dist/Height: VF 2.5/ ; CB 1.6/5;

rficial Material; I/SC; D/SC; —/—; D/SP; —/—; I/CL;
(Origin / Type) (I=*in situ*; D=deposited; F=failed; CL=clay, ML=silt, SP=sand, GP=gravel)

pe of Accreted Sediment; SP (N=none, SP=sand, ML=silt, CL=clay); Sample taken; ✓ (Check)

pe of Process; MW; MW, D; —; D; —; F;
none-stable, MW=mass wasting, F=fluvial erosion, , S=Sapping, D=deposition)

L/R	#	Type of Process Yr	Dep	Fal[1]	Location (VF,UB, SL, etc)	Amt. Deposit (cm)	Bl. W (m)	Dendro/Remarks Type[2]	D (cm)	Date/ Age	Sp.	Rate of Wid./Dep.
R	1			2°	UB	—	3.6	EG	14	germ 1990	sweet gum	ecc '92
R	2	✓	—		DS	—	—	—	18	germ 90	"	surface age
R	3			L	UB	—	1.2	—	11.5	germ 90	"	failure in 1990
R	4	—		L	UB	—	1.2	—	10.0	germ 90	"	
	5	✓	—		DS	—	—	—	29	19 years	red oak	surface age
	6	✓	—		UB	—	—	—	15.5	germ 83	"	"
R	7			2°	UB	—	3.5	TS	1.5	92	sweet gum	[illegible]
	8											
	9											
	10											

Type of Process— Fal = Failure Type (S=slab (vertical drop), L=linear, R=rotational, 2°=secondary)
Sample = (TS=tilt sprout, RS=root to stem wood, EG=eccentric growth, RH=exposed root hairs; BS=buried stem)
e/Age = Specify either date of failure or number of years since failure

Figure 6--Example field form used for geomorphic evaluations.

Bank Sketch:

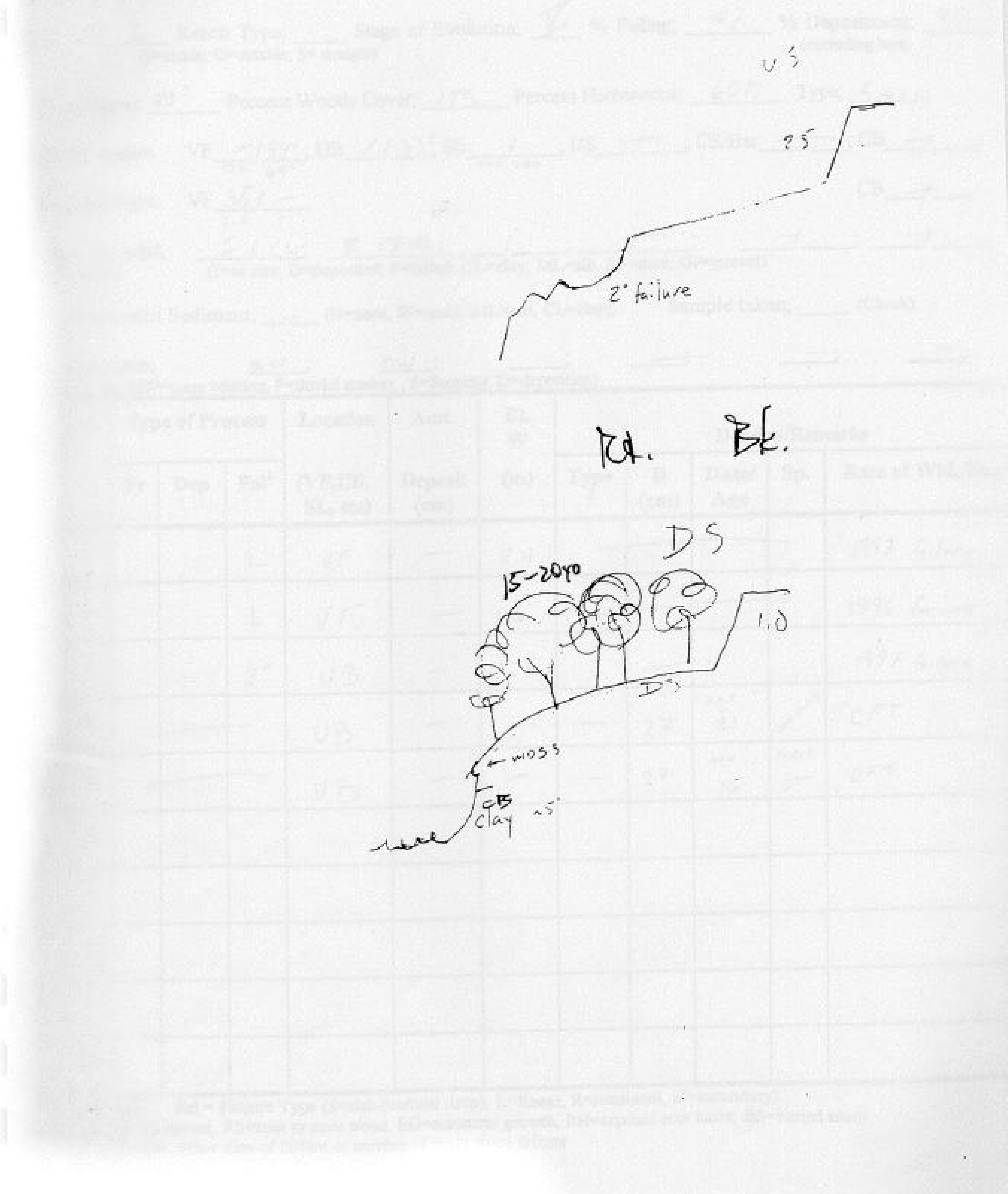


Figure 6--Example field form used for geomorphic evaluations.

Bank Description:

Side (L; R): L Reach Type; ____ (I=inside; O=outside; S= straight) Stage of Evolution; V % Failing; 92 % Depositional; 70 (excluding bars)

Aspect (degrees); 20° Percent Woody Cover; 10% Percent Herbaceous; 60% Type; [illegible]

Surfaces / Angles VF ✓/54° (DS 64°); UB ✓/33°; SL ___/___ (incised); DS —/—; CS/Bar —/—; CB —/—;

Slope-dist/Height: VF 35/— (2.5 —); CB —/—;

Surficial Material; I / CL; F / 19 ML; ___/___; —/—; —/—; —/—;
(Origin / Type) (I=*in situ*; D=deposited; F=failed; CL=clay, ML=silt, SP=sand, GP=gravel)

Type of Accreted Sediment; — (N=none, SP=sand, ML=silt, CL=clay); Sample taken; ____ (Check)

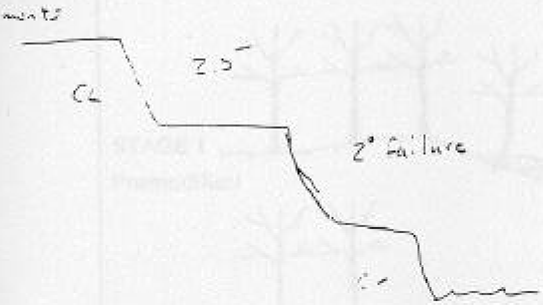
Type of Process; MW; MW; ___; —; —; —;
(N=none-stable, MW=mass wasting, F=fluvial erosion, , S=Sapping, D=deposition)

L/R	#	Type of Process			Location	Amt.	Bl. W	Dendro/Remarks				
		Yr	Dep	Fal[1]	(VF,UB, SL, etc)	Deposit (cm)	(m)	Type[2]	D (cm)	Date/ Age	Sp.	Rate of Wid./Dep.
L	1			L	VF	—	2.4	—	—	—	—	1997 failure
L	2			L	VF	—	1.6	—	—	—	—	1996 failure
L	3			2°	UB	—	1.5		—	—		1997 failure
L	4	—	—	—	UB	—	—	—	27	age 21	[illegible]	CFT
L	5	—	—	—	VB	—	—	—	27	age 16	sweet gum	CFT
	6											
	7											
	8											
	9											
	10											

[1] Type of Process— Fal = Failure Type (S=slab (vertical drop), L=linear, R=rotational, 2°=secondary)
[2] Sample = (TS=tilt sprout, RS=root to stem wood, EG=eccentric growth, RH=exposed root hairs; BS=buried stem)
Date/Age = Specify either date of failure or number of years since failure

Figure 6--Example field form used for geomorphic evaluations.

Bank Sketch: LB



Photographs: Camera; A.S.'s Minolta; Photographer; JH

No. 17; Subject F. L Bk Looking D/S @ 400' U/S Br @ B1

No. 18; Subject from B1 bridge DS

No. 19; Subject " US

No. 20; Subject " US → RB cars

No. _____; Subject

No. _____; Subject

No. _____; Subject

No. _____; Subject

No. _____; Subject

No. _____; Subject

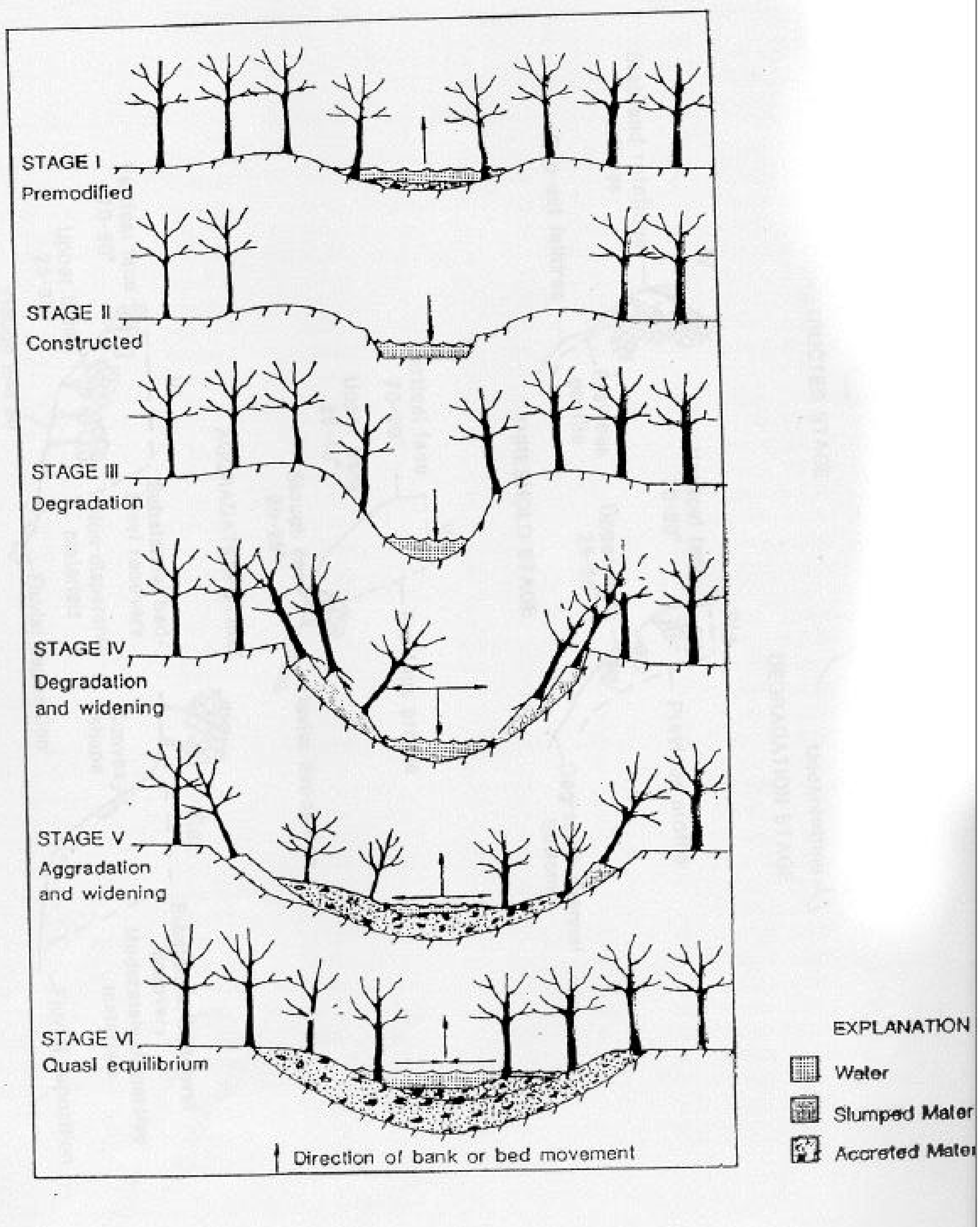


Figure 7--Six-stage model of channel evolution (Simon and Hupp, 1986).

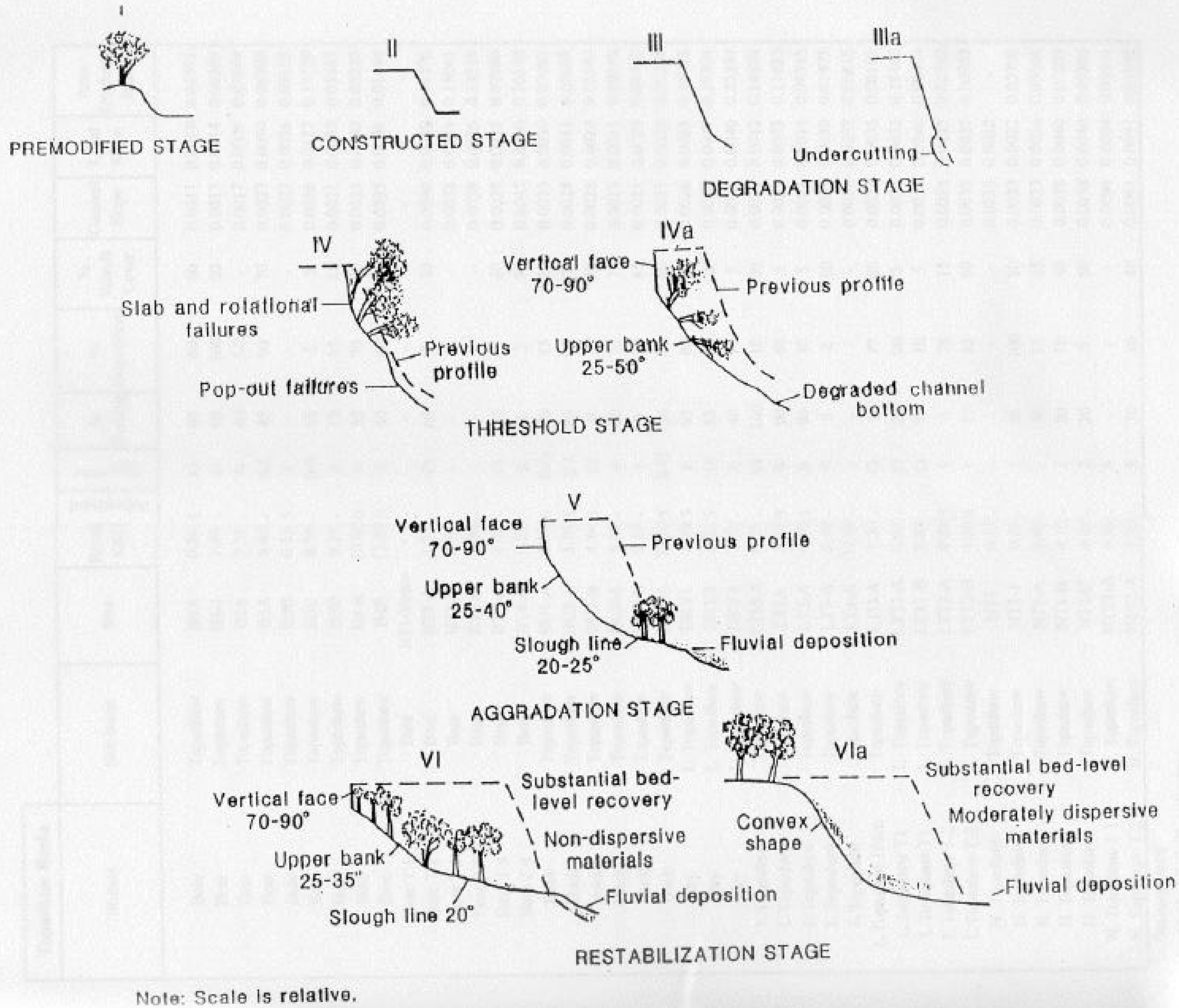


Figure 19 - Channel depths of tributaries to the "upper" Yalobusha River.

Table 3 - Summary of field data collected for geomorphic evaluations.

Topashaw Basin

Stream	Sub-basin	Site	River KM	Basin RKM	D.A.* (km^2)	Bed** Material	Bed d_{50}	Acc. d_{50}	Bed Control	Planform***	Knickpoints	Total Hieght	Top Width	Berm Width	Bottom Width	Left Stage	Earlier Adjustment	Type****	% Failing	% Deposition	% Woody Cover	Right Stage	Earlier Adjustment	Type****	% Failing	% Deposition	% Woody Cover	General Slope	Local Slope	Area-Gradient-Index
Bear	Topashaw	B1A	0.86	18.26	48.5	CL	0.01	0.27	CL	MS	1	0.3	23	8.6	4.5	5	5	-	98	70	10	5	5	O	60	60	60	0.0011	0.0019	0.05391
Bear	Topashaw	B2-1	1.40	18.80	48.3	SP	3.84	-	None	MS	0	0	30.5	20.8	5.4	5	-	I	80	100	10	5	-	O	70	100	20	0.0013	0.0014	0.06369
Bear	Topashaw	B2A	3.50	20.90	48	GP	0.7	0.12	None	ST	4	1.9	-	20.5	8.8	5	-	S	70	2	-	5	-	S	40	5-?	-	0.0017	0.0009	0.07945
Bear	Topashaw	B3A	5.45	22.85	34.6	CL	0.49	0.08	CL	ST	3	-	22	11.2	3.8	4	5	S-O	95	-	25	5	-	S-I	45	90	70	0.0027	0.0030	0.09208
Bear	Topashaw	B3B	6.25	23.65	33.9	CL	-	-	CL	MS	2	0.5	26	11.5	6.1	4	5	O	90	10	15	4	5	I	-	-	-	0.0027	0.0036	0.09153
Bear	Topashaw	B3C	8.50	25.90	24.7	CL	-	-	CL	M	1	0.5	15.5	-	7.7	4	-	I-S	100	5	2	4	-	0-S	95	2	5	0.0056	0.0127	0.13729
Bear	Topashaw	B3D	9.24	26.64	14.9	CL	0.02	-	CL	ST	0	0	9.5	-	5.4	3	-	S	15	0	80	3	-	S	15	15	85	0.0021	0.0035	0.03167
Bear	Topashaw	B4-A	10.84	28.24	12.8	CL	0.07	0.36	CL	MS	0	0	9.5	-	4.9	4	6	-	85	0	40	3	6	S	35	70	80	0.0025	0.0030	0.03239
Bear	Topashaw	B4B	13.20	30.60	4.16	GP	12.9	0.04	None	MS	0	0	13.9	-	3.6	3	5	-	50	15	55	3	5	S	60	40	75	0.0035	0.0036	0.01444
Bear T 1	Bear	BT1-Notes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear T 2	Bear	BT2-A	1.74	23.40	41.8	CL	0.05	-	CL	MS	0	0	12.2	-	1.7	3	-	I	2	10	50	4	-	O	60	2	30	0.0040	0.0038	0.16576
Bear T 2	Bear	BT2-B	3.18	24.84	39.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0038	0.0041	0.15041
Bear T 2	Bear	BT2-C	1.26	22.92	37.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0038	0.0026	0.14219
Bear T 3	Bear	BT3-A	1.03	26.53	28.2	CL	0.02	-	CL	MS	0	0	6.5	-	-	3	-	I	1	2	95	3	-	O	30	2	60	0.0028	0.0035	0.07896
Bear T 4	Bear	BT4-A	0.54	26.12	22.8	CL	0.018	-	CL	S	0	0	8	-	1.5	4	-	S	50	2	70	3	-	S	2	2	80	0.0045	0.0100	0.10194
Buck	Topashaw	BU1-A	1.31	21.51	20.2	CL	0.007	0.37	CL	MS	5	1.85	18.6	-	6.9	3	6	S-I	15	20	80	4	6	S-O	70	15	20	0.0035	0.0039	0.07085
Buck	Topashaw	BU2-A	3.14	23.34	20.11	CL-SP	0.2	-	CL	MS	1	0.15	13	9.2	5.9	4	5	S-O	70	85	10	4	5	S-I	85	95	2	0.0028	0.0011	0.05650
Buck	Topashaw	BU2-B	4.14	24.34	19.8	CL	-	-	CL	M	1	-	9	5.8	5.1	3	5	I	5	90	20	3	5	O	0	50	20	0.0028	0.0024	0.05544
Buck	Topashaw	BU3-A	5.01	25.21	18.2	SP	0.29	-	None	S	1	0.5	6.8	-	5.8	3	5	S-O	15	20	80	3	-	S	20	10	75	0.0017	0.0011	0.03078
Buck	Topashaw	BU3-B	9.54	29.74	11.17	SP	-	-	None	M	0	0	9.6	-	4.2	3	-	O	60	95	50	3	-	I	0	80	85	0.0021	0.0023	0.02332
Buck	Topashaw	BU5-A	13.10	33.30	4.1	SP	0.51	0.17	None	MS	0	0	6.6	-	3.6	3	5	S-I	25	98	75	3	5	S-O	20	98	80	0.0031	0.0028	0.01261
Dry	L. Topashaw	DRY1	2.30	28.36	65.8	GP	0.08	0.21	None	S	0	0	12.2	6.9	3.5	4	5	O	95	10	2	4	5	I	95	80	2	0.0026	0.0025	0.16973
Dry	L. Topashaw	DRY2	3.22	29.28	65.4	CL	0.89	0.21	CL	MS	0	0	20.7	6.5	2.2	5	-	I	80	40	2	-	5	O	85	20	2	0.0031	0.0037	0.20304
Dry	L. Topashaw	DRY3	5.01	31.07	61.2	CL	-	-	CL	MS	1	0.3	12.6	6	3.4	3.5	-	S	25	20	10	3.5	-	S	40	10	5	0.0041	0.0040	0.25354
L.Topashaw	Topashaw	LTM-A	0.78	25.46	68.8	SP	0.28	0.27	None	M	0	0	45	22.5	7.5	6	-	I	0	100	30	4	-	O	100	10	30	0.0021	0.0012	0.14304
L.Topashaw	Topashaw	LT1A	3.15	27.83	56.3	CL	0.012	0.26	CL	MS	1	0.65	22.5	11.4	7.9	4	5	S	85	70	5	4	5	S	90	40	5	0.0021	0.0033	0.11823
L.Topashaw	Topashaw	LT2-A	4.50	29.18	21.5	CL	0.009	0.24	CL	MS	1	0.2	16.7	10.5	5.7	4	5	S	60	50	40	4	5	S	90	80	5	0.0021	0.0014	0.04515
L.Topashaw	Topashaw	LT3-A	9.40	34.08	5.9	CL-GP	0.06	-	CL	S	0	0	5.6	-	3.1	3	-	S	5	10	80	3	-	S	5	2	60	0.0033	0.0033	0.01975
L.Topashaw	Topashaw	LT4-A	11.00	35.68	2.47	GP	0.91	0.21	CL	MS	0	0	6.1	-	3.3	6	-	-	-	-	-	3	-	-	-	-	-	0.0033	0.0033	0.00815
L.Topashaw Ditch	Topashaw	LTD-A	1.36	24.99	0.6	SP-CL	0.06	0.12	None	MS	0	0	19.5	9.3	1.3	6	-	I	0	90	85	5	-	O	5	??	80	0.0033	0.0035	0.00196
L.Topashaw T1	L. Topashaw	LTT1-A	0.63	28.75	54.16	SP	0.8	-	None	MS	1	0.35	13	8.5	5	5	-	I	10	80	10	5	-	O	20	90	5	0.0034	0.0032	0.18405
L.Topashaw T1	L. Topashaw	LTT1-B	2.84	30.96	27.66	SP-GP	0.43	0.2	None	MS-S	0	0	12	7.2	3.1	5	-	I	2	98	80	4	-	O	70	10	5	0.0034	0.0040	0.09404
L.Topashaw T-2	L. Topashaw	LTT2-A	0.29	34.02	6.68	CL	0.003	0.019	CL	MS	3	0.4	8.9	-	4.3	3	5	O	20	20	15	3	5	I	5	75	15	0.0035	0.0035	0.02363
L.Topashaw T-2	L. Topashaw	LTT2-B	1.39	35.12	2.13	CL	-	-	CL	MS	1	0.25	7.7	-	2.7	4	5	O	80	10	1	3	6	I	15	15	90	0.0035	0.0035	0.00753
N. Topashaw	Topashaw	NT1	0.15	27.66	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0023	0.0022	-
N. Topashaw	Topashaw	NT1-1	0.25	27.76	25.2	CL	0.03		CL	MS	0	0	39	15.8	6.6	5	-	O	40	90	5	5	-	I	0	100	80	0.0023	0.0022	0.05796
N. Topashaw	Topashaw	NT1-A	1.45	28.96	24.2	CL	21.55	0.23	CL	MS	1	0.4	33.5	-	9.5	4	-	O	85	5	0	4	-	I	30	15	45	0.0023	0.0026	0.05566
N. Topashaw	Topashaw	NT1-B	4.16	31.67	13.8	CL	-	-	CL	MS	3	1.4	10.1	-	5	4	-	O	100	0	30	3	-	I	20	10	40	0.0038	0.0040	0.05259
N. Topashaw	Topashaw	NT1-C	4.41	31.92	13.7	CL	-	-	CL	MS	1	0.3	7.1	-	4.1	3	-	O	10	0	70	3	-	I	20	5	60	0.0038	0.0040	0.05206
N. Topashaw T 1	N. Topashaw	NTT1-A	0.92	30.43	0.64	CL	0.07	-	ST	S	1	1.6	3.7	-	2	3	-	S	-	-	-	3	-	S	-	-	-	0.0094	0.0094	0.00601
N. Topashaw T 2	N. Topashaw	NTT2-A	1.29	31.04	4.75	CL	-	-	CL	S	1	0.7	16.2	-	5.2	3	-	S	40	2	80	3	-	S	30	10	80	0.0041	0.0041	0.01942

* - Drainage area

** - Unified Soil Classification

*** - Planform (S - Straight; MS - Mildly Sinuous; M - Meandering)

**** -Type (I - Inside; S - Straight; O - Outside)

Table 3 (cont') - Summary of field data collected for geomorphic evaluations.

Topashaw Basin

Stream	Sub-basin	Site	River KM	Basin RKM	D.A.* (km^2)	Bed** Material	Bed d_{50}	Acc. d_{50}	Bed Control	Planform***	Knickpoints	Total Hieght	Top Width	Berm Width	Bottom Width	Left Stage	Earlier Adjustment	Type****	% Failing	% Deposition	% Woody Cover	Right Stage	Earlier Adjustment	Type****	% Failing	% Deposition	% Woody Cover	General Slope	Local Slope	Area-Gradient-Index
Topashaw	Yalobusha	TM-A	0.61	4.65	275.2	SP	0.3	0.16	None	S	0	0	-	33.7	-	6	-	S	2	98	90	6	-	S	0	100	100	0.0003	0.0009	0.07080
Topashaw	Yalobusha	TM-B	1.94	5.98	269.07	SP	0.3	0.16	None	S	0	0	-	30.4	-	6	-	S	0	100	80	6	-	S	0	100	85	0.0003	0.0001	0.08072
Topashaw	Yalobusha	TM-C	3.85	7.89	265.15	SP	0.24		None	S	0	0	35	21	-	6	-	S	2	100	90	6	-	S	2	100	90	0.0003	0.0004	0.07955
Topashaw	Yalobusha	T1-A	5.56	9.60	260.42	SP	0.28	0.19	None	S	0	0	-	34.4	-	6	-	S	0	100	90	6	-	S	5	100	90	0.0004	0.0004	0.10727
Topashaw	Yalobusha	T2-A	7.31	11.35	255.66	SP	-	-	None	S	0	0	35	28.1	17.2	6	-	S	5	98	90	6	-	S	5	98	90	0.0003	0.0003	0.08945
Topashaw	Yalobusha	T2-B	8.07	12.11	255.43	CL	0.37	-	CL	MS	0	0	44	31.7	11.9	6	-	S	25	98	95	6	-	I	5	95	90	0.0003	0.0003	0.07663
Topashaw	Yalobusha	T2-C	9.97	14.01	248.45	CL	0.39	-	CL	S	1	0.4	44.4	32.6	16.6	5	-	S	30	100	40	5	-	S	30	100	30	0.0005	0.0006	0.11345
Topashaw	Yalobusha	T2-D	12.70	16.74	231.68	SP	0.45	-	None	S	0	0	66	35.1	14.1	5	-	S	10	100	60	5	-	S	60	100	10	0.0005	0.0001	0.12528
Topashaw	Yalobusha	T3	13.90	17.94	173.15	SP	0.48	0.19	None	S	0	0	25	17	8.7	5	-	S	80	98	20	5	-	S	60	98	50	0.0005	0.0008	0.08658
Topashaw	Yalobusha	T4	17.60	21.64	137.73	CL	0.011	0.19	CL	S	1	0.4	31	19.1	10.4	5	-	S	70	85	75	5	-	S	70	98	60	0.0008	0.0007	0.10869
Topashaw	Yalobusha	T4-A	19.30	23.34	129.8	SP	-	-	None	MS	1		43	30	11.5	5	-	S	50	100	90	6	-	S-I	0	100	90	0.0008	0.0005	0.10011
Topashaw	Yalobusha	T5	20.60	24.64	124.47	CL-SP	2.88	0.22	CL	MS	0	0	35	13.5	7.7	5	-	I	70	80	30	5	-	O	85	20	15	0.0018	0.0013	0.21992
Topashaw	Yalobusha	T6-A	23.60	27.64	22.94	CL	5.86	0.24	CL	S	1	-	34.2	15.2	4.8	4	-	O-S	80	15	5	5	-	I	10	80	20	0.0018	0.0016	0.04129
Topashaw	Yalobusha	T7	26.10	30.14	19.57	CL	1.27	0.17	CL	MS	0	0	32.6	-	7.2	4	-	I	95	20	10	4	-	O	90	50	5	0.0031	0.0022	0.05972
Topashaw	Yalobusha	T7-A	27.10	31.14	15.13	CL	4.21	-	CL-STR	S	1	0.5	19.5	-	5.8	4	-	I	98	0	2	4	-	S	95	30	2	0.0031	0.0025	0.04690
Topashaw	Yalobusha	T9-A	28.90	32.94	8.08	CL	11.86	-	CL	MS	0	0	22.2	-	3.8	4	-	S	80	70	15	4	-	S	95	10	20	0.0043	0.0044	0.03455
Topashaw	Yalobusha	T10	29.80	33.84	2.48	CL	0.06	-	CL	MS	0	0	8.5	-	2.6	3	-	S	70	2	40	3.5	-	S	75	5	80	0.0043	0.0045	0.01066
Topasahw T 1	Topashaw	TT1-A	2.07	21.32	12.67	CL	0.23	3.54	CL	S	4	3.7	-	11.8	8.2	4	-	S	70	2	60	4	-	S	-	-	-	0.0028	0.0023	0.03545
Topasahw T 1	Topashaw	TT1-B	3.49	22.74	8.8	CL	1.04	0.24	CL	MS	2	1.3	13.1	-	6.8	3.5	-	S	50	20	80	3.5	-	S	70	10	50	0.0023	0.0023	0.01984
Topasahw T 2	Topashaw	TT2-A	2.77	29.41	2.9	CL	1.58	-	CL	S	0	0	7	-	3.1	3	-	S	10	5	0	3	-	S	10	5	0	0.0037	0.0037	0.01077
Topashaw T 3	Topashaw	TT3-A	0.12	31.12	18.4	GP-SP	3.89	-	-	S	1	1.45	15.4	-	2.6	4	-	I-O	80	10	0	4	-	O-I	80	30	0	0.0091	0.0091	0.16750
Topashaw T 3	Topashaw	TT3-B	0.75	31.74	18.2	CL	-	-	CL-ST-RR	S	-		6.1	-	2.4	3	-	S	5	0	10	3	-	S	10	0	0	0.0091	0.0091	0.16562
Topashaw T 4	Topashaw	TT4-A	0.13	31.46	11.6	SP	1.12	-	CL	MS	-	0	20	-	2	4	-	O	0	0	0	4	-	I	0	0	0	0.0068	0.0067	0.07928
Topashaw T 4	Topashaw	TT4-B	1.99	33.32	9.73	CL	-	-	CL	S	-	-	8.6	-	2	3	-	S	0	0	70	3	-	S	0	0	70	0.0068	0.0054	0.06616

* - Drainage area

** - Unified Soil Classification

*** - Planform (S - Straight; MS - Mildly Sinuous; M - Meandering)

**** -Type (I - Inside; S - Straight; O - Outside)

Table 3 (cont') - Summary of field data collected for geomorphic evaluations.

Yalobusha Basin

Stream	Sub-basin	Site	River KM	Basin RKM	D.A.* (km^2)	Bed** Material	Bed d_{50}	Acc. d_{50}	Bed Control	Planform***	Knickpoints	Total Hieght	Top Width	Berm Width	Bottom Width	Left Stage	Earlier Adjustment	Type****	% Failing	% Deposition	% Woody Cover	Right Stage	Earlier Adjustment	Type****	% Failing	% Deposition	% Woody Cover	General Slope	Local Slope	Area-Gradient-Index
Anderson	Duncan	A1-A	1.37	25.78	10	GP	-	-	None	MS	0	0	5.4	-	3.8	3	-	I	5	40	30	3	-	S	0	20	20	0.0047	0.0050	0.04703
Big	Yalobusha	Big-M-A	1.04	5.54	40.5	SP	0.29	0.17	None	MS	0	0	12.5	-	-	6	-	I	0	100	100	6	-	O	0	100	100	0.0004	0.0004	0.01620
Big	Yalobusha	Big1	1.26	5.76	40.5	SP	-	-	None	S	0	0	-	-	-	6	-	-	-	-	-	6	-	-	-	-	-	0.0012	0.0004	0.04922
Big	Yalobusha	Big2	1.92	6.42	34.9	SP	-	-	None	MS	0	0	-	-	-	5	-	-	-	-	-	5	-	-	-	-	-	0.0012	0.0006	0.04188
Big	Yalobusha	Big2-A	2.79	7.29	34.02	SP	0.45	0.18	None	MS	0	0	20.9	15.5	7.2	5	-	S	90	80	35	5	-	S	10	100	10	0.0010	0.0010	0.03304
Big	Yalobusha	Big3	3.00	7.50	33.8	-	-	-	-	MS	0	0	-	-	-	5	-	-	-	-	-	5	-	-	-	-	-	0.0010	0.0010	0.03380
Big	Yalobusha	Big4	4.50	9.00	33	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	4	-	-	-	-	-	0.0010	0.0010	0.03196
Big	Yalobusha	Big5-A	5.75	10.32	30	SP	0.36	0.19	None	MS	0	0	24.2	14.8	6.6	5	-	S	50	80	50	5	-	S	60	80	40	0.0014	0.0011	0.04138
Big	Yalobusha	Big5-B	6.24	10.87	23.3	SP	0.49	-	None	S	0	0	31.2	9.6	4.7	5	-	S	50	80	35	5	-	S	60	85	5	0.0014	0.0009	0.03262
Big	Yalobusha	Big5-B1	6.40	11.00	22	CL	-	-	CL	S	5	1.8	20.3	-	7.3	4	-	S	70	25	2	4	-	S	70	20	10	0.0014	0.0009	0.03080
Big	Yalobusha	Big5-C	6.80	11.33	21.8	CL	0.41	-	CL	MS	1	1.4	26.6	15	13.4	5	5	I	25	85	-	5	5	O	30	40	-	0.0005	0.0009	0.01106
Big	Yalobusha	Big5-D	7.73	12.15	19.2	SP	0.43	-	None	MS	0	0	24.6	12.8	3.7	5	-	S	40	90	20	5	-	S	85	5	2	0.0014	0.0009	0.02700
Big	Yalobusha	Big6	8.21	12.71	17	SP	0.03	-	None	MS	0	0	23	-	3	5	-	S	10	70	80	5	-	S	90	70	40	0.0014	0.0012	0.02380
Big	Yalobusha	Big6-A	8.38	12.88	16.05	CL	-	-	None	M	1	0.3	19.5	-	-	4	-	O	95	5	15	5	-	I	10	100	75	0.0014	0.0012	0.02247
Big	Yalobusha	Big7-A	10.77	15.27	6.17	CL	0.13	-	CL	MS	2	0.9	11.2	-	3	3	6	S	5	20	90	3	6	S	45??	10	70	-	-	-
Big	Yalobusha	Big7-B	15.69	20.19	4.37	GP	-	-	AR	MS	2	0.5	6.9	-	2.8	3	6	O	10	2	95	3	6	I	10	2	95	-	-	-
Bull	Yalobusha	Bull 1	1.10	26.80	8.6	CL	0.02	-	STR	S	1	2.1	10.6	-	7.1	4	-	-	-	-	-	4	-	-	-	-	-	0.0032	0.0063	0.02756
Bull	Yalobusha	Bull2	1.90	27.60	7.72	CL	-	-	CL	S	1	0.4	11.8	-	4.5	4	6	S	95	50	35	4	6	S	70	0	10	0.0032	0.0048	0.02501
Bull	Yalobusha	Bull2-A	2.04	27.74	7.51	CL	-	-	CL	MS	0	0	6	-	2.5	3	6	I	20	2	95	4	6	O	90	2	90	0.0032	0.0048	0.02403
Bull	Yalobusha	Bull2-A 1	2.10	27.80	7.51	CL	-	-	CL	S	0	0	5.8	-	4.2	-	-	-	-	-	-	-	-	-	-	-	-	0.0032	0.0048	0.02403
Bull	Yalobusha	Bull2-B	2.36	28.06	5.82	CL	-	-	CL	MS	2	0.4	4.5	-	3.1	3	6	S	5	0	98	3	6	S	20	0	95	0.0032	0.0024	0.01862
Bull	Yalobusha	Bull2-C	2.52	28.22	5.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0032	0.0023	0.01824
Bull	Yalobusha	Bull3	3.87	29.57	4.04	CL	-	-	CL	S	0	0	5.2	-	4.6	6	-	S	10	85	75	6	-	S	0	90	80	0.0005	0.0007	0.00185
Bull T 1	Bull	Bull T1-A	0.97	1.86	0.89	GP	-	-	CL	S	0	0	2.6	-	1.6	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Cane(Cook)	Yalobusha	C0-A	1.91	24.62	63.9	CL	0.43	0.21	CL	S	1	0.35	27.3	18.2	11.6	5	-	S	80	90	70	5	-	S	75	95	60	0.0019	0.0016	0.11927
Cane(Cook)	Yalobusha	C1-A	3.25	25.96	57.8	CL	9.07	0.23	CL	MS	0	0	24	12.4	6.1	5	-	I	80	100	80	4	-	O	100	20	15	0.0016	0.0025	0.08990
Cane(Cook)	Yalobusha	C2-A	7.20	29.91	48.1	SP-CL	0.32	0.2	CL	MS	0	0	23.5	14.9	8.3	5	-	O	80	90	90	5	-	S-I	80	85	60	0.0018	0.0015	0.08613
Cane(Cook)	Yalobusha	C2-B	8.95	31.66	40.9	CL	-	-	CL	S	0	0	25.8	-	14.5	4	-	I	100	5	40	4	-	O	100	0	45	0.0021	0.0016	0.08505
Cane(Cook)	Yalobusha	C2-B1	9.04	31.75	36.03	CL	-	-	CL	S	0	0	24.5	-	12.4	4	-	-	-	-	-	4	-	-	-	-	-	0.0021	0.0016	0.07566
Cane(Cook)	Yalobusha	C2-C	10.70	33.41	32.8	CL	-	-	CL	MS	4	0.7	17.6	12.5	7.1	4	5	S-O	85	20	40	4	-	S-I	80	20	45	0.0030	0.0030	0.09824
Cane(Cook)	Yalobusha	C3-A	10.99	33.70	30.8	CL	7.63	-	CL		1	0.4	17	-	5.3	4	-	-	80	-	20	4	-	-	75	-	20	0.0030	0.0030	0.09240
Cane(Cook)	Yalobusha	C3-B	11.27	33.98	28.3	CL	-	-	CL	S	2	0.5	16.8	-	6	4	-	S	70	0	35	4	-	S	80	0	20	0.0030	0.0030	0.08490
Cane(Cook)	Yalobusha	C4-A	13.27	37.89	20.7	SP	0.93	-	CL	S	0	0	6.9	-	4	3	-	S	5	2	90	3	-	S	20	5	90	0.0033	0.0028	0.06783
Dry	Cane (Cook)	DC1-A	0.60	26.53	53.7	CL	0.09	-	CL	S	0	0	6.5	-	3.3	4	-	S	90	0	100	4	-	S	80	0	90	0.0030	0.0039	0.15991
Dry	Cane (Cook)	DC2-A	3.25	29.18	21.9	CL	0.027	-	CL	MS	0	0	7.3	-	2.5	4	-	S	80	20	80	4	-	S	80	10	50	0.0049	0.0049	0.10804
Duncan	Yalobusha	DM-A	2.37	18.77	18.5	SP	-	-	CL	MS	0	0	22	10.8	5	5	-	O	30	95	70	5	-	I	5	100	85.7	0.0020	0.0020	0.03612
Duncan	Yalobusha	D2-A	5.64	22.04	12.7	SP	-	-	None	MS	0	0	15.6	9.8	4.1	4	-	S	15	90	90	4	-	S	90	80	95	0.0022	0.0022	0.02750
Duncan	Yalobusha	D3-A	8.94	25.34	7.8	SP-CL	-	-	CL	MS	0	0	14.9	10.8	3.2	4	-	S	25	2	80	4	-	S	70	20	65	0.0030	0.0027	0.02306
Fair	Yalobusha	FM-B	4.53	38.17	14.4	CL	0.009	-	CL	S	0	0	7.4	-	2.2	-	-	-	-	-	-	-	-	-	-	-	-	0.0012	0.0015	0.01775
Fair	Yalobusha	F2-A	8.01	41.65	4.6	CL	-	-	CL	S	1	1.2	3.1	-	1.5	3	-	-	-	-	-	-	-	-	-	-	-	0.0027	0.0050	0.01236
Gordon	Mud	GBM	1.27	30.58	29	CL	0.02	-	CL	MS	0	0	8.3	-	3.4	3	-	S	10	10	0	3	-	S	10	10	0	0.0013	0.0014	0.03735
Gordon	Mud	GB1-A	4.90	35.42	47.8	CL	0.013	-	CL	S	0	0	3.2	-	2.2	3	-	S	2	2	90	3	-	S	-	2	20	0.0019	0.0017	0.09016
Gordon	Mud	GB2-A	6.44	36.96	45.5	CL	-	-	CL	S	0	0	1.9	-	1.8		-	-	-	-	-	-	-	-	-	-	-	-	-	-

* - Drainage area

** - Unified Soil Classification

*** - Planform (S - Straight; MS - Mildly Sinuous; M - Meandering)

**** -Type (I - Inside; S - Straight; O - Outside)

Table 3 (cont') - Summary of field data collected for geomorphic evaluations.

Yalobusha Basin

Stream	Sub-basin	Site	River KM	Basin RKM	D.A.* (km^2)	Bed** Material	Bed d_{50}	Acc. d_{50}	Bed Control	Planform***	Knickpoints	Total Hieght	Top Width	Berm Width	Bottom Width	Left Stage	Earlier Adjustment	Type****	% Failing	% Deposition	% Woody Cover	Right Stage	Earlier Adjustment	Type****	% Failing	% Deposition	% Woody Cover	General Slope	Local Slope	Area-Gradient-Index
Huffman	Hurricane	Huf-4-A	1.90	16.90	21.9	SP	-	-	None	S	0	0	22.4	12.4	6.6	5	-	S	10	98	50	5	-	S	10	100	70	0.0017	0.0015	0.03715
Huffman	Hurricane	Huf-4-B	4.51	19.51	16.3	SP	0.25	-	CL	S	1	-	18	10.5	7.6	3	5	S	10	10	85	4	5	S	95	30	10	0.0022	0.0006	0.03662
Huffman T 1	Huffman	HT1-A	0.90	20.60	9.72	SP	0.45	-	CL	S	0	0	9	-	4	4	-	S	80	10	10	3	-	S	10	2	80	0.0036	0.0031	0.03517
Huffman T 1	Huffman	HT1-B	2.15	21.85	8.59	CL	0.031	-	CL	MS	0	0	6.2	-	3.2	3	-	S-I	10	10	85	5	-	I	15	65	75	-	-	-
Hurricane	Hurricane	HM-A	0.52	11.20	24.91	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	6	-	-	-	-	-	0.0007	0.0001	0.01766
Hurricane	Hurricane	H2-A	2.23	12.91	23.2	CL	-	-	CL	MS	0	0	17.8	11	6.8	5	-	S	30	73	60	6	-	S	2	98	100	0.0014	0.0013	0.03219
Hurricane	Yalobusha	Hur-3A	5.58	16.26	14.42	SP	-	-	None	S	0	0	15.5	10.5	6.9	5	5	S	10	85	65	5	5	S	15	40	80	0.0014	0.0043	0.02019
Hurricane	Yalobusha	Hur-3B	7.78	18.46	11.92	SP	-	-	None	S	0	0	19	10.7	5.6	5	-	S	5	60	80	5	-	S	50	80	30	0.0023	0.0035	0.02719
Hurricane	Yalobusha	Hur 4	7.78	18.46	11.92	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	4	-	-	-	-	-	0.0023	0.0035	0.02742
Hurricane	Walnut	HW1-A	2.80	35.18	5.51	CL	-	-	CL	S	0	0	-	-	2.9	3	-	S-I	5	2	95	4	-	S-O	90	2	90	0.0029	0.0041	0.01611
Johnson	Yalobusha	JM-A	0.15	28.87	21.99	CL	0.02	-	CL	M	1	0.8	11.1	-	6.2	4	-	O	99	0	10	4	-	I	99	10	10	0.0047	0.0052	0.10370
Johnson	Yalobusha	JM-B	0.68	29.05	21.93	CL	-	-	CL	M	1	0.3	9.6	-	9	4	-	O	98	0	15	4	-	I	98	2	10	0.0047	0.0049	0.10307
Johnson	Yalobusha	JM-C	0.96	29.28	21.91	CL	-		CL	S	0	0	6.2	-	3.7	3	-	S	0	0	0	3	-	S	0	0	15	0.0047	0.0043	0.10298
Johnson	Yalobusha	J1-A	1.21	29.96	15.9	CL	1.53	-	CL	S	2	0.25	6.4	-	3.6	3	-	S	15	0	85	3	-	S	15	0	80	0.0017	0.0017	0.02681
Johnson	Yalobusha	J1-B	4.18	32.93	7.91	GP			None	MS	1	0.3	7.6	-	4.1	3	-	S-O	20	10	90	3	-	S-I	20	20	95	0.0022	0.0027	0.01776
Johnson T 1	Johnson	JT1-A	1.80	33.01	2.23	CL	0.012	-	CL	S	1	0.8	7.5	-	2.4	4	-	S	85	5	10	4	-	S	30	5	20	-	-	-
Johnson T 2	Johnson	JT2-1	4.77	36.02	8.34	GP	-	-	CL	MS	0	0	5.8	-	2.2	6	-	-	-	-	-	6	-	-	-	-	-	-	-	-
Lick	Mud	L1-A	2.78	35.78	47.71	CL	-	-	CL	S	0	0	3.5	-	2.7		-	-	-	-	-		-	-	-	-	-	0.0015	0.0013	0.07195
Lick	Mud	L2-A	6.72	39.72	37.84	CL	-	-	CL	S	0	0	2.3	-	2.3	3	-	S	-	-	0	3	-	S	0	20	0	0.0032	0.0035	0.12134
Meridian	Yalobusha	MerM-A	2.48	23.47	26.2	SP	-	-	CL	MS	1	0.15	20	10.2	6.7	6	-	I	15	75	90	6	-	O	20	80	85	0.0020	0.0019	0.05323
Meridian	Yalobusha	Mer2-A	4.04	25.03	24.7	SP	-	-	CL	MS	0	0	25.8	16.7	7	6	-	S	10	90	98	6	-	S	2	90	70	0.0012	0.0020	0.02851
Meridian	Yalobusha	Mer3-A	5.88	26.87	22	CL	-	-	CL	MS	1	0.25	23	9.1	5	5	-	O	80	90	20	5	-	I	75	80	70	0.0021	0.0020	0.04688
Meridian	Yalobusha	Mer3-B	8.20	29.19	14.9	CL	-	-	CL	MS	0	0	22.1	-	6.7	3	-	S	5	5	90	3	-	S	10	10	90	0.0022	0.0020	0.03295
Meridian	Yalobusha	Mer4-A	9.24	30.23	11.61	CL	6.41	-	CL	MS	0	0	16.6	-	9.3	3	-	I	10	20	70	3	-	O	15	0	60	0.0022	0.0020	0.02554
Meridian	Yalobusha	Mer4-B	10.11	31.10	5.47	CL	-	-	CL	MS	0	0	12	-	5.9	3	-	I-O	25	20	80	3	-	I-O	10	30	75	0.0040	0.0040	0.02184
Meridian	Yalobusha	Mer5-A	12.52	33.51	3.3	SP	-	-	CL	M	0	0	10.5	-	2.9	6	-	I	20	5	70	6	-	O	5	95	95	0.0040	0.0040	0.01320
Meridian T 1	Meridian	MerT1M-A	10.16	41.26	4.4	GP(clay)	10.63	-	None	MS	0	0	14	-	5.1	3	-	I	0	0	90	3	-	O	40	10	80	-	-	-
Meridian T 1	Meridian	MerT1M-B	11.22	42.32	2.84	CL	-	-	CL	MS	1	0.3	9.7	-	3.9	3	-	I	0	10	35	3	-	O	15	0	20	-	-	-
Meridian T 1	Meridian	MerT1M-C	12.11	43.21	1.99	GP(clay)	-	-	CL	S	1	0.8	8.3	-	3.3	3	-	S	0	0	10	3	-	S	0	0	10	-	-	-
Meridian T 2	Meridian	MerT2 - A	12.83	45.48	24.68	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	6	-	-	-	-	-	-	-	-
Miles	Yalobusha	M1-A	1.11	14.64	15.3	CL	0.07	0.24	CL	MS	1	0.15	12.1	5.7	3	3	6	O	0	90	80	3	6	I	0	40	90	0.0024	0.0021	0.03606
Miles	Yalobusha	M2-A	2.55	16.08	13.4	SP	0.28	0.21	None	S	1	2.1	11	9.2	7.2	6	-	S	1	90	90	6	-	S	0	90	95	0.0008	0.0008	0.01128
Miles	Yalobusha	M4	5.95	19.48	6.58	CL	-	-	None	M	0	0	4.5	-	3.5	6	-		2	95	90	6	-		2	95	90	0.0030	0.0020	0.01985
Mud	Yalobusha	MU1-A	1.95	29.16	35.7	CL	2.6	-	CL	MS	0	0	22.1	-	5	4	-	I	90	40	75	4	-	O	100	5	2	0.0017	0.0033	0.06083
Mud	Yalobusha	MU1-B	2.15	29.36	26.02	CL	-	-	CL	S	1	1.2	12.4	-	7.7	4	-	S	80	40	0	4	-	S	100	0	0	0.0020	0.0033	0.05106
Mud	Yalobusha	MU1-B1	2.32	29.53	26	CL	-	-	CL	S	0	0	9.1	-	-	3	-	-	-	-	-	3	-	-	-	-	-	0.0020	0.0017	0.05200
Mud	Yalobusha	MU1-C	3.31	30.52	23.6	CL	-	-	CL	S	0	0	9.7	-	5.7	3	-	S	10	0	0	3	-	S	10	0	0	0.0014	0.0017	0.03333
Mud	Yalobusha	MU1-D	5.79	33.00	26.9	CL	-	-	CL	S	0	0	10.3	-	6.8	3	-	S	0	0	0	3	-	S	0	5	0	0.0009	0.0015	0.02339
Mud	Yalobusha	MU1-E	7.66	34.87	23.6	CL	-	-	CL	MS	0	0	11.2	-	4.4	3	-	S	10	10	95	3	5	S	0	5	80	0.0008	0.0014	0.01924
Mud	Yalobusha	MU4-A	10.60	37.81	18.3	CL	0.014	-	CL	MS	0	0	8.8	-	3.2	3	-	O	20	2	90	3	-	S	0	2	95	0.0014	0.0014	0.02601
Mud	Yalobusha	MU4-B	14.60	42.73	8.28	CL	-	-	CL	MS	0	0	13.3	-	3.7	3	-	I-O	40	10	80	3	6	O	-	2	90	0.0023	0.0025	0.01937
Mud	Yalobusha	MU6-A	17.20	44.41	2.06	CL	0.026	-	CL	S	0	0	3.9	-	2.7	2	-	-	-	-	-	-	-	-	-	-	-	0.0023	0.0043	0.00474

* - Drainage area

** - Unified Soil Classification

*** - Planform (S - Straight; MS - Mildly Sinuous; M - Meandering)

**** -Type (I - Inside; S - Straight; O - Outside)

Table 3 (cont') - Summary of field data collected for geomorphic evaluations.

Yalobusha Basin

Stream	Sub-basin	Site	River KM	Basin RKM	D.A.* (km^2)	Bed** Material	Bed d_{50}	Acc. d_{50}	Bed Control	Planform***	Knickpoints	Total Hieght	Top Width	Berm Width	Bottom Width	Left Stage	Earlier Adjustment	Type****	% Failing	% Deposition	% Woody Cover	Right Stage	Earlier Adjustment	Type****	% Failing	% Deposition	% Woody Cover	General Slope	Local Slope	Area-Gradient-Index
Mud T 1	Mud	MT1-A	1.41	30.50	58.52		0.02	-								3	-	-	-	-	-	3	-	-	-	-	-	0.0026	0.0102	0.15221
Mud T 3	Mud	MUT3-A	0.47	40.86	0.5	SP	-	-	CL	S	0	0	2.7	-	1.8	3	-	-	-	-	-	3	-	-	-	-	-	0.0046	0.0046	0.00230
Naron	Johnson	NM-A	0.01	25.26	21.7	CL	-	-	CL	S	3	1.6	5.3	-	0.8	4	-	S	100	0	10	4	-	S	95	0	15	0.0027	0.0027	0.05940
Naron	Johnson	NM-A-1	0.14	25.39	21.7	CL	-	-	CL	S	0	0	5	-	-	3	-	S	20	0	75	3	-	S	15	0	70	0.0027	0.0027	0.05859
Naron	Johnson	NM-B	6.78	32.03	21.5	CL	-	-	CL	S	0	0	5.7	-	2.8	3	-	S	-	-	-	3	-	S	-	-	-	-	-	-
Naron	Johnson	N1-A	11.30	36.55	9.26	CL	1.7	-	CL	S	0	0	7.8	-	1.9	3	6	S	2	20	85	3	6	S	10	5	85	-	-	-
Splunge	Yalobusha	SM-B	2.05	9.64	12.2	SP	-	-	None	S	0	0	11.3	-	6.7	6	-	S	0	100	0	6	-	S	0	0	100	0.0014	0.0008	0.01754
Splunge	Yalobusha	S2-A	2.59	10.18	11.6	CL	-	-	CL	MS	0	0	17.3	-	4.7	5	-	I	5	90	0	5	-	O	20	75	0	0.0014	0.0015	0.01624
Splunge	Yalobusha	S2-B	4.08	11.67	10.5	CL	0.53	-	CL	S	1	0.3	13.2	-	4.3	4	-	S	60	20	0	4	-	S	60	50	0	0.0018	0.0035	0.01899
Splunge	Yalobusha	S2-C	4.48	12.07	8.2	CL	-	-	CL	S	1	0.7	11.4	-	3.8	4	-	S	70	15	0	4	-	S	95	5	0	-	-	-
Splunge	Yalobusha	S2-D	4.56	12.15	8.2	CL	0.04	-	CL	S	1	0.4	9.1	-	5.1	3	-	S	25	0	30	3	-	S	10	20	80	-	-	-
Twin	Huffman	TW-M-A	11.35	22.39	5	CL	0.15	0.29	CL	S	0	0	10.1	5.9	2.3	3	5	S	5	85	80	3	5	S	10	50	95	0.0038	0.0039	0.01890
Walnut	Cane (Cook)	WM-A	0.07	33.52	24.9	CL	-	-	CL	S	1	0.45	21.6	-	8.6	4	-	-	-	-	-	4	-	-	-	-	-	0.0031	0.0031	0.07829
Walnut	Cane (Cook)	W1-A	2.59	36.04	14.6	CL	3.63	0.3	CL	MS	1	-	11.5	-	2.7	4	-	S-I	70	75	2	4	-	S-O	95	80	2	0.0031	0.0031	0.04526
Walnut	Cane (Cook)	W2-A	4.68	38.13	4.2	CL	1.84	-	CL	S	1	0.3	-	-	2.6	4	-	S	50	10	95	4	-	S	20	10	80	0.0038	0.0061	0.01578
Walnut T 1	Walnut	WT1-1	1.93	39.96	0.6	CL	-	-	CL	MS	0	0	2.4	-	1.5	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Yalobusha	Yalobusha	YM-A	3.66	3.66	865	SP	0.27	0.02	None	S	0	0	55	-	-	6	-	S	0	100	100	6	-	S	0	100	100	0.0001	0.0001	0.08650
Yalobusha	Yalobusha	YM-B	4.83	4.83	557	SP	0.32	0.16	None	M	0	0	42	-	-	6	-	I	0	100	100	6	-	O	0	100	100	0.0001	0.0001	0.05570
Yalobusha	Yalobusha	YM-C	6.62	6.62	547	SP	0.32	0.18	None	S	0	0	33.5	-	-	6	-	S	0	100	100	6	-	S	0	100	100	0.0001	0.0001	0.05470
Yalobusha	Yalobusha	YM-D	7.98	7.98	522	SP	0.32	0.18	None	S	0	0	36	-	-	6	-	S	0	100	100	6	-	S	0	100	100	0.0001	0.0001	0.05220
Yalobusha	Yalobusha	YM-E	9.34	9.34	520	SP	0.39	0.19	None	S	0	0	95.3?	36.4	-	5	-	S	40	100	100	6	-	S	0	100	95	0.0001	0.0001	0.06641
Yalobusha	Yalobusha	Y1	10.50	10.50	507	SP	-	-	None	S	0	0	-	-	-	6	-	-	-	-	-	6	-	-	-	-	-	0.0004	0.0008	0.21726
Yalobusha	Yalobusha	Y1-A	11.08	11.08	457	SP	0.35	0.1	None	S	0	0	-	30.4	-	5	-	S	20	100	100	6	-	S	60	100	90	0.0004	0.0008	0.19449
Yalobusha	Yalobusha	Y1-B	12.87	12.87	432	SP	0.37	0.18	None	MS	0	0	-	41.5	-	6	-	S	0	100	90	5	-	S	25	100	98	0.0006	0.0007	0.25286
Yalobusha	Yalobusha	Y2-A	14.49	14.49	409	SP	0.02	-	None	S	0	0	-	24	14.3	6	-	S	5	100	90	6	-	S	5	100	80	0.0006	0.0023	0.23976
Yalobusha	Yalobusha	Y2-B	16.12	16.12	404	SP	0.3	0.22	None	MS	0	0	-	36.8	13.1	6	-	S	0	100	90	6	-	S	10	100	90	0.0006	0.0024	0.23702
Yalobusha	Yalobusha	Y2-C	17.84	17.84	379	SP	0.6	0.19	None	S	0	0	-	38.1	12.9	5	-	S	20	100	85	5	-	S	20	100	50	0.0005	0.0001	0.17249
Yalobusha	Yalobusha	Y2-F	25.00	25.00	248	SP	-	-	None	S	0	0	-	-	-	5	-	-	-	-	-	5	-	-	-	-	-	0.0005	0.0013	0.11266
Yalobusha	Yalobusha	Y3-A	25.70	25.70	230	CL	14.45	0.025	CL	S	1	0.5	35.2	22.7	11.8	5	-	S	0	100	70	5	-	S	0	100	85	0.0010	0.0013	0.23343
Yalobusha	Yalobusha	Y3-B	27.20	27.20	218	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0010	0.0003	0.22199
Yalobusha	Yalobusha	Y3-C	28.30	28.30	139	CL	-	-	CL	M	0	0	??	15.7	7.8	5	-	O	85	65	65	5	-	I	2	98	95	0.0010	0.0009	0.14212
Yalobusha	Yalobusha	Y3-D	28.60	28.60	139	CL	-	-	CL	M	0	0	36.5	-	7.9	4	-	O	95	2	45	5	-	I	5	98	80	0.0010	0.0016	0.14268
Yalobusha	Yalobusha	Y3-E	28.80	28.80	139	CL	-	-	CL	M	1	1.4	16.6	-	6	3	-	I	0	0	20	4	-	O	85	0	10	0.0010	0.0024	0.14329
Yalobusha	Yalobusha	Y3-F	32.90	32.90	103	CL	-	-	CL	M	0	0	7.3	-	3.8	3	-	S	0	10	85	3	-	S	0	0	90	0.0006	0.0007	0.05749
Yalobusha	Yalobusha	Y-4	33.40	33.40	102.6	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-		-	-	-	-	-	0.0006	0.0007	0.05721
Yalobusha	Yalobusha	Y4-A	33.50	33.50	102	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	3	-	-	-	-	-	0.0006	0.0007	0.05687
Yalobusha	Yalobusha	Y5-A	34.80	34.80	75.7	CL	0.01	-	CL	M	1	0.3	10.4	-	4.1	3	-	I	0	2	50	4	-	O	80	2	25	0.0006	0.0007	0.04231
Yalobusha	Yalobusha	Y-6	43.90	43.90	28.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0006	0.0007	0.01585
Yalobusha	Yalobusha	Y-7	46.10	46.10	26.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yalobusha	Yalobusha	Y-8	54.40	54.40	7.89	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yalobusha T 1	Yalobusha	YT1-1-A	2.73	14.61	14.7	GP	-	-	CL	S	0	0	11.2	-	5.2	3	-	S	10	0	5	3	-	S	0	0	40	0.0020	0.0020	0.02907
Yalobusha T 2	Yalobusha	YT2-A	2.02	32.27	8.92	CL	-	-	CL	S	0	0	4.2	-	2.8	3	-	-	-	-	-	3	-	-	-	-	-	0.0011	0.0011	0.00956
Yalobusha T 2	Yalobusha	YT2-B	4.36	34.61	2.9	CL	-	-	CL	S	1	0.6	3	-	1.7	4	-	-	80	-	-	4	-	-	40	-	-	0.0022	0.0022	0.00626

* - Drainage area

** - Unified Soil Classification

*** - Planform (S - Straight; MS - Mildly Sinuous; M - Meandering)

**** -Type (I - Inside; S - Straight; O - Outside)

Table 4 Stages of channel evolution

No.	Stage Name	Dominant processes: Fluvial	Dominant processes: Hillslope	Characteristic forms	Geobotanical evidence
I	Premodified	Sediment transport-mild aggradation; basal erosion on outside bends; deposition on inside bends.	—	Stable, alternate channel bars; convex top-bank shape; flow line high relative to top bank; channel straight or meandering.	Vegetated banks to low-flow line
II	Constructed	—	—	Trapezoidal cross section; linear bank surfaces; flow line lower relative to top bank.	Removal of vegetation (?)
III	Degradation	Degradation; basal erosion on banks.	Pop-out failures	Heightening and steepening of banks; alternate bars eroded; flow line lower relative to top bank.	Riparian vegetation high relative to flow line and may lean towards channel.
IV	Threshold	Degradation; basal erosion on banks.	Slab, rotational and pop-out failures.	Large scallops and bank retreat; vertical-face and upper-bank surfaces; failure blocks on upper bank; some reduction in bank angles; flow line very low relative to top bank.	Tilted and fallen riparian vegetation.
V	Aggradation	Aggradation; development of meandering thalweg; initial deposition of alternate bars; reworking of failed material on lower banks.	Slab, rotational and pop-out failures; low-angle slides of previously failed material.	Large scallops and bank retreat; vertical-face, upper bank, and slough line; flattening of bank angles; flow line low relative to top bank; development of new flood plain (?).	Tilted and fallen riparian vegetation; reestablishing vegetation on slough line; deposition of material above root collars of slough-line vegetation.
VI	Restabilization	Aggradation; further development of meandering thalweg; further deposition of alternate bars; reworking of failed material; some basal erosion on outside bends deposition on flood plain and bank surfaces.	Low-angle slides; some pop-out failures near flow line.	Stable, alternate channel bars; convex-short vertical face, on top bank; flattening of bank angles; development of new flood plain (?); flow line high relative to top bank.	Reestablishing vegetation extends up slough line and upper bank; deposition of material above root collars of slough-line and upper-bank vegetation; some vegetation establishing on bars.

Table 4--Six stage model of channel evolution (Simon, 1989).

(2) The onset of channel widening by mass-wasting processes is associated with aggradation on the channel bed in the Schumm et al., (1984) model (stage III; Figures 6-7, p. 128), thereby disregarding the occurrence of channel widening during degradation.

In the Simon and Hupp (1986) model, mass failures of bank material are identified earlier in the adjustment sequence (stage IV), prior to the onset of aggradation when the channel is still degrading its bed.

In alluvial channels, disruption of the dynamic equilibrium often results in some amount of upstream channel degradation and downstream aggradation. Using the Simon and Hupp (1986) model we can consider the equilibrium channel as the initial, predisturbed stage (I) of channel evolution, and the disrupted channel as an instantaneous condition (stage II). Rapid channel degradation of the channel bed ensues as the channel begins to adjust (stage III, Figure 5). Degradation flattens channel gradients and consequently reduces the available stream power for given discharges with time. Concurrently, bank heights are increased and bank angles are often steepened by fluvial undercutting and by pore-pressure induced bank failures near the base of the bank. Thus, the degradation stage (III) is directly related to destabilization of the channel banks and leads to channel widening by mass-wasting processes (stage IV) once bank heights and angles exceed the critical shear-strength conditions of the bank material. The aggradation stage (V) becomes the dominant trend in previously degraded downstream sites as degradation migrates further upstream because the flatter gradient at the degraded site cannot transport the increased sediment loads emanating from degrading reaches upstream. This secondary aggradation occurs at rates roughly 60% less than the associated degradation rate (Simon, 1992). These milder aggradation rates indicate that bed-level recovery will not be complete and that attainment of a new dynamic equilibrium (stage VI) will take place through further (1) bank widening and the consequent flattening of bank slopes, (2) the establishment and proliferation of riparian vegetation that adds roughness elements, enhances bank accretion, and reduces the stream power for given discharges, and (3) further gradient reduction by meander extension and elongation.

Mass wasting of banks begins to occur on the outside of bends during stage III in the Yalobusha River System and in other streams where incision has occurred in mildly sinuous or meandering reaches. The bank-stability conditions are referred to as “transition.” It is because of the sinuosity of some of the streams in the Yalobusha River System that we adopted the practice of assigning a stage of channel evolution to each bank. Plots of stage of channel evolution versus distance above the mouth may, therefore, show values of 3.5, 4.5, or 5.5.

Bed Conditions

Samples of the channel bed were taken at each of the evaluation sites to (1) identify relative resistance to erosion, (2) interpret the dominant process acting on the channel bed (degradation or aggradation), and (3) identify sources of coarse material. Plentiful sand or gravel deposits generally indicate aggradational conditions (stages V or VI) while in the Yalobusha River System the presence of a clay bed generally indicates degradational conditions (stages III or IV). Natural or engineered bed-level controls were noted. The presence of knickpoints was noted, and in most cases, their height was measured. An overfall due to a structure such as a culvert was also noted as a knickpoint because it represented a local steepening of the stream profile.

Bank Conditions

Channel banks were described by reach type (inside, outside, or straight), longitudinal extent of bank failures and sediment deposition (in percent), aspect, percent woody cover (growing on bank surfaces), and percent herbaceous cover. The type of process active on each bank/geomorphic surface was identified along with the type of surficial sediment. Processes were separated into:

1. none-stable (transport),
2. mass wasting (bank failure)
3. fluvial erosion
4. sapping (pop-out failure), and
5. deposition.

Identification and sampling of sediments accreted on bank surfaces was also undertaken. The presence of accreted sediments (sands) is indicative of a depositional (stage V or VI) environment, although care must be exercised to assure that the depositional process is recent and active and not a relic feature. In addition, the age of the oldest woody-riparian plant was determined as a measure of the length of time that a particular bank surface had been stable.

CHANNEL CONDITIONS

The sediment/debris plug on the lower Yalobusha River downstream of Calhoun City is of critical importance to channel-adjustment processes and conditions in the river system by serving as a blockage to the downstream transport of sediment. Sediment/debris plugs have been a relatively common phenomenon over the past 60 years in this watershed. This is related to the channel morphology conditions imposed in 1967 at the transition between the dredged and straightened channel upstream, and the un-maintained sinuous reaches downstream (Figure 9). Sediment-transport capacity at this transition probably drops significantly, causing relatively rapid sediment deposition. Plugs have formed further upstream in the late 1930's and in 1940 on lower Topashaw Creek. The present plug is shown in Figure 10 as a large hump in the 1997 thalweg profile of the lower Yalobusha River. The 1969 and 1970 profiles obtained from the National Resources Conservation Service (NRCS) indicate that the plug was already beginning to form, just 2 years after the completion of the channel work. It has grown steadily since this time with eroded sediment from upstream reaches and tributaries, and woody vegetation from destabilized streambanks. Time series cross sections taken by the NRCS at river kilometer 3.55 (cross section Y-1) show this initially rapid deposition following the 1967 channel work (Figure 11).

A comparison of the 1967 and 1997 channel profiles shows that as much as 7 m of sediment and debris has accumulated on the channel bed of the Yalobusha River. Very flat (0.0001 m/m) or even negative channel gradients extend to about river kilometer 10 (Figure 12), particularly on the Yalobusha River, producing lake-like conditions downstream from Calhoun City. Bank heights downstream of the plug are about 2 m high. The sediment/debris plug also directly effects the downstream-most 2 km of Topashaw Creek where as much as 2 m of deposition has occurred since 1967 (Figure 12).

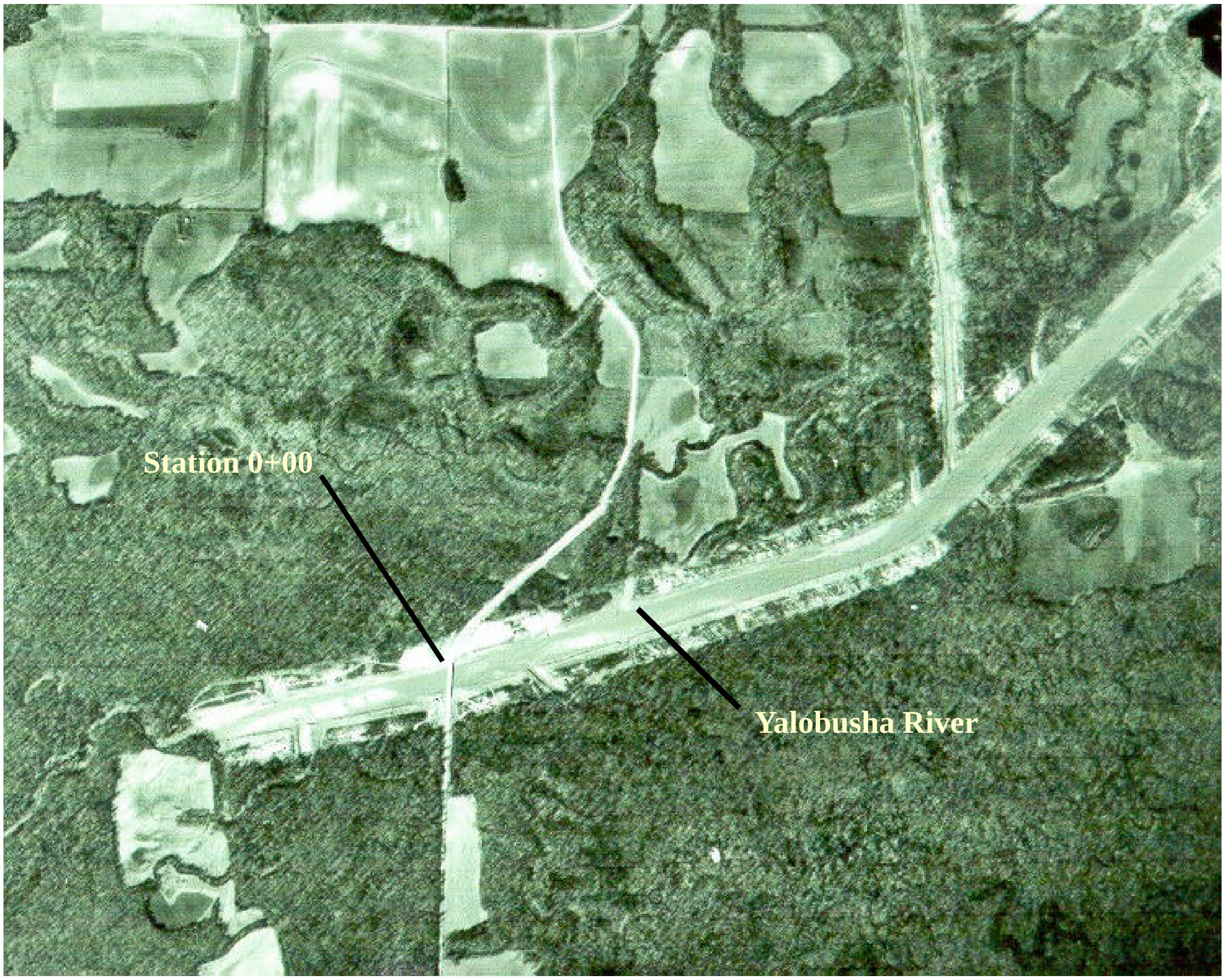


Figure 9 -- Photograph taken in 1969 of transition area between channelized section and "natural" sinuous section of the Yalobusha River main stem.

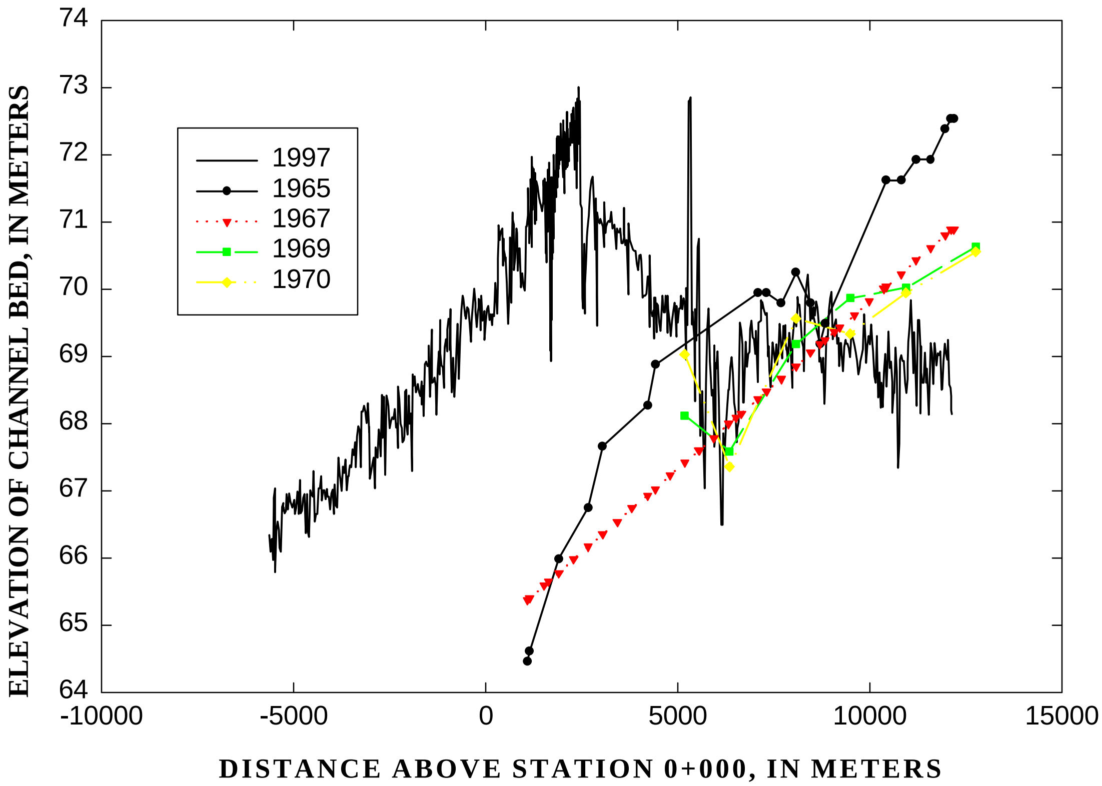


Figure 10--Thalweg profiles of lower Yalobusha River in the vicinity of the sediment/debris plug, showing initial development in 1969, 2 years after the completion of the most recent channel work.

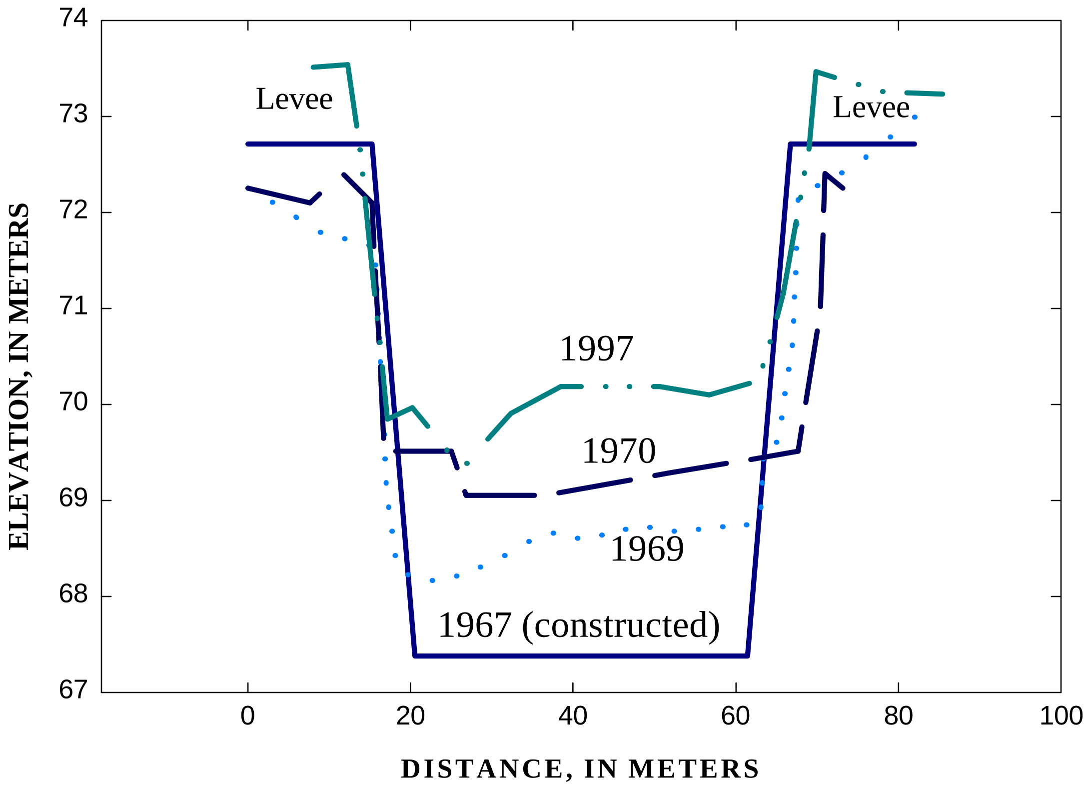


Figure 11--Time-series cross-section surveys for Yalobusha River at river kilometer 3.55 (Y-1) showing rapid deposition.

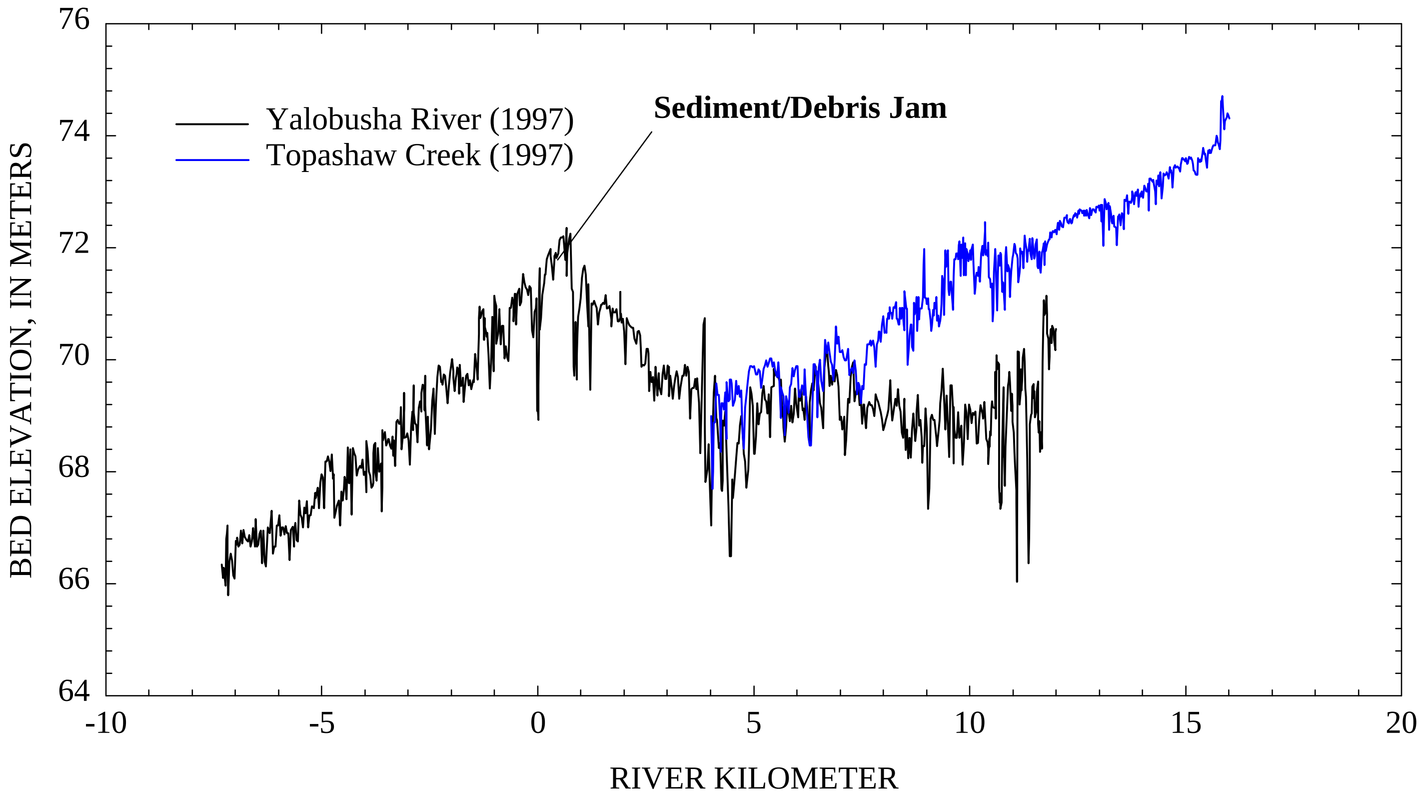


Figure 12--Thalweg profiles of lower Yalobusha River and Topashaw Creek Showing extremely flat and even negative, local channel-gradients.

Stage VI Stable Conditions

In some regards, the Yalobusha River System has responded similarly to other channelized stream systems in Mississippi, West Tennessee, and other areas of the mid-continent region. In downstream reaches, main stem channels are characterized by aggradation, sediment accretion on channel banks, the proliferation of "pioneer" woody-riparian species such as willow, river birch and sweet gum and the regaining of bank stability. Channel beds are characterized by fine to medium sand. These reaches extend from river kilometer –7.4 to 9.2 on the Yalobusha River, 8.0 km upstream on Topashaw Creek, and are in stage VI of the Simon and Hupp (1986) channel evolution model.

A relation between drainage area and channel gradient (slope) for stage VI conditions was established for the Yalobusha River System (r^2 = 0.68) (Figure 13):

$$S = .003564\, A^{-0.4229} \tag{1}$$

Where S = channel gradient, in m/m; and A = drainage area, in km^2. Table 5 provides all of the data points included in the stage VI relation along with a comparison of predicted versus observed values. The r^2 value for the relation indicates that about 32% of the variance remains unexplained. This is probably due to:

(1) exceptionally low gradient values in the most downstream reaches of the Yalobusha River and Topashaw Creek because of the sediment/debris plug, and
(2) greatly decreased availability of sand-sized bed sediment from upstream reaches because of exposure of clay beds.

Because of the potential bias towards very flat slopes at large drainage areas, use of equation 1 may produce "stable" gradient values that are overly conservative (flat). Table 6 provides a comparison of predicted (using equation 1) versus observed gradients for all sites other than the stage VI sites. By removing the 5 sites on the Yalobusha River downstream of the Highway 8 bridge that are directly impacted by the sediment/debris plug, the equation becomes (r^2 = 0.63) (Figure 13):

$$S = .002794\, A^{-0.3298} \tag{2}$$

This equation may be a more realistic predictor of "stable" gradients for the Yalobusha River System particularly for large drainage areas in that the exponent is similar to those derived for the Coldwater River System (U.S. Army Corps of Engineers, 1993). Predicted equilibrium slopes using the modified stage VI equation (equation 2) are provided in Table 7.

Stage V Conditions

With increasing distance upstream, evidence of mass failures can be observed as bank heights increase to more than 10 m even though deposition of sand-sized materials is still evident. These stage V conditions begin at about river kilometer 9.2 - and 8.0, on the Yalobusha River and Topashaw Creek, respectively (Plate 2). The stage V gradient relation is provided for comparison (Figure 14). Note that the exponent of the stage V relation (0.3222) is similar to the exponent in equation (2), representing free-flowing stage VI conditions.

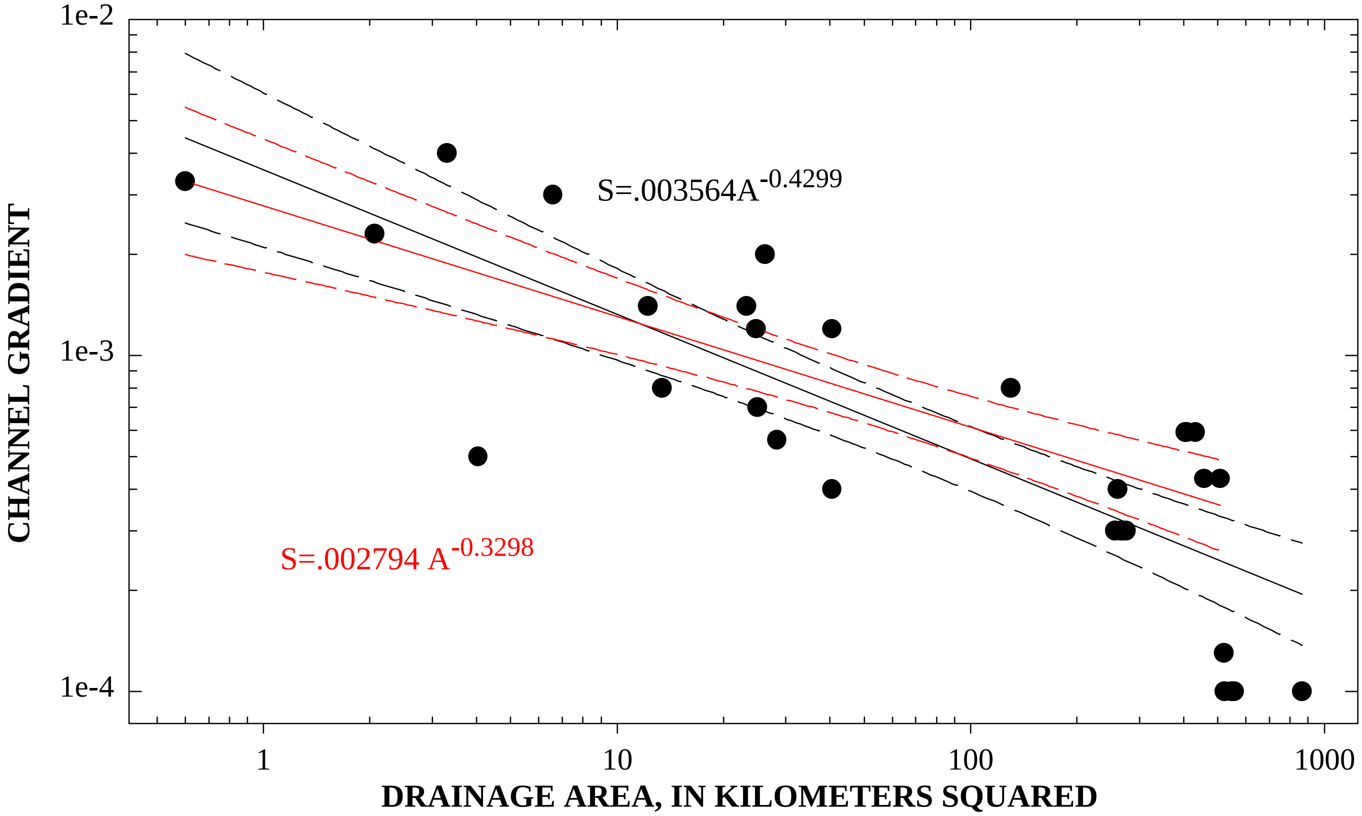


Figure 13--Stage VI stable-slope relations. Relation in red is without 5 most downstream sites on the Yalobusha River

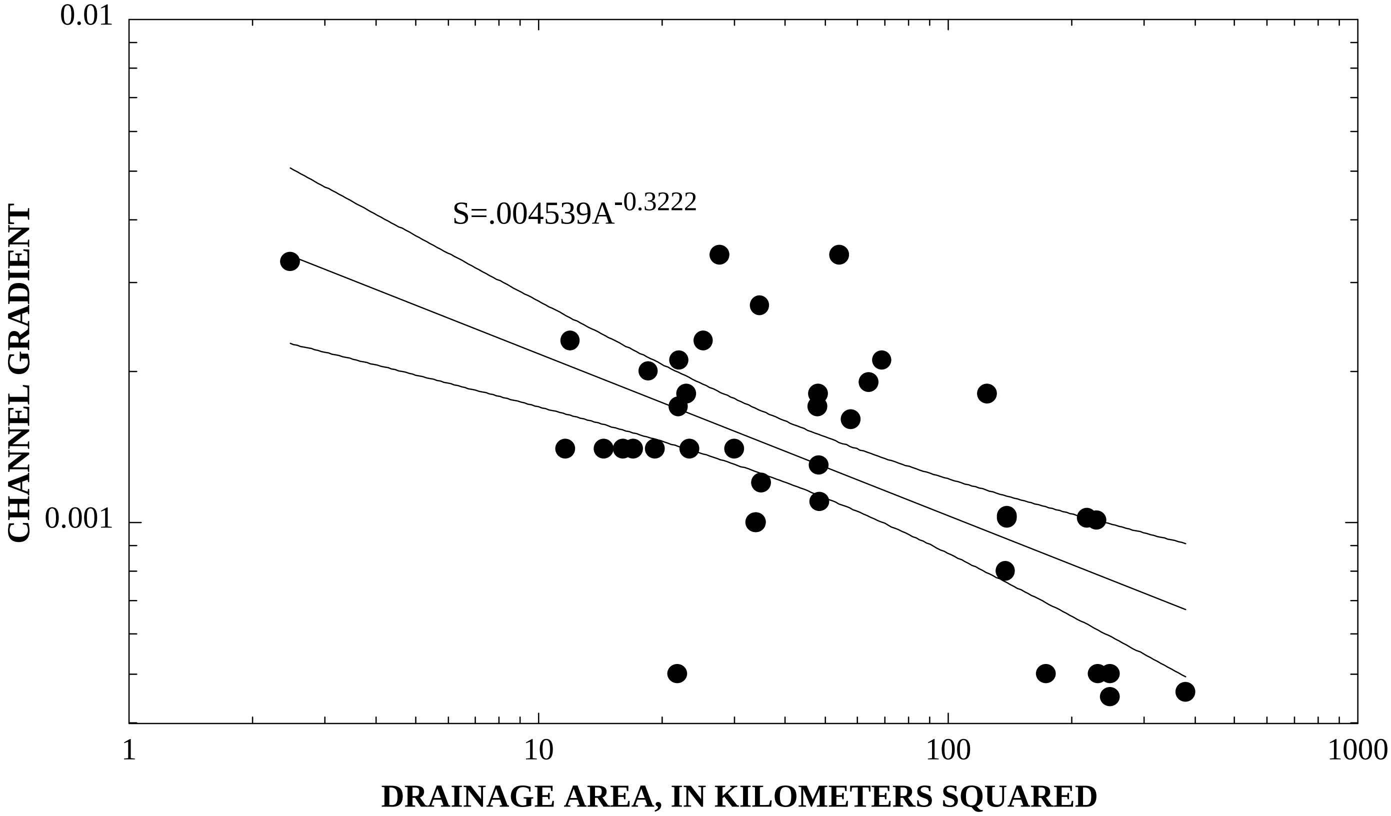


Figure 14--Stage V stable-slope relation.

Table 6--Predicted stable slopes for reaches currently (1997) in stage III, IV, or V using stage VI stable-slope relation (equation 1; See Figure 13).

Stream	River Kilometer	Drainage Area (km^2)	Stage	Observed Slope	Predicted Equilibrium Slope	Difference (%)
Anderson	1.37	10.0	3	0.00470	0.00132	-71.8
Bear	0.86	48.5	5	0.00111	0.00067	-39.6
Bear	1.40	48.3	5	0.00132	0.00067	-49.0
Bear	3.50	48.0	5	0.00166	0.00067	-59.2
Bear	5.45	34.6	5	0.00266	0.00078	-70.8
Bear	6.25	33.9	4	0.00270	0.00078	-71.0
Bear	8.50	24.7	4	0.00556	0.00090	-83.8
Bear	9.24	14.9	3	0.00213	0.00112	-47.5
Bear	10.84	12.8	3	0.00253	0.00119	-52.9
Bear	13.20	4.16	3	0.00347	0.00193	-44.4
Bear T 2	1.74	41.8	4	0.00397	0.00072	-81.9
Bear T 3	1.03	28.2	3	0.00280	0.00085	-69.7
Bear T 4	0.54	22.8	3	0.00447	0.00093	-79.2
Big	1.92	34.9	5	0.00120	0.00077	-35.5
Big	2.79	34.0	5	0.00097	0.00078	-19.4
Big	3	33.8	5	0.00100	0.00078	-21.5
Big	4.5	33.0	4	0.00097	0.00079	-18.2
Big	5.75	30.0	5	0.00138	0.00083	-40.1
Big	6.24	23.3	5	0.00140	0.00092	-34.2
Big	6.40	22.0	4	0.00140	0.00094	-32.6
Big	6.80	21.8	5	0.00051	0.00095	86.8
Big	7.73	19.2	5	0.00141	0.00100	-28.8
Big	8.21	17.0	5	0.00140	0.00105	-24.7
Big	8.38	16.1	4.5	0.00140	0.00108	-22.8
Big	10.77	6.17	3	-	0.00163	-
Big	15.69	4.37	3	-	0.00189	-
Buck	1.31	20.2	4	0.00351	0.00098	-72.1
Buck	3.14	20.1	4	0.00281	0.00098	-65.1
Buck	4.14	19.8	3	0.00280	0.00099	-64.7
Buck	5.01	18.2	3	0.00169	0.00102	-39.5
Buck	9.54	11.2	3	0.00209	0.00126	-39.5
Buck	13.10	4.10	3	0.00308	0.00194	-36.8
Bull	1.1	8.60	4	0.00321	0.00141	-55.9
Bull	1.9	7.72	4	0.00324	0.00148	-54.3
Bull	2.04	7.51	3.5	0.00320	0.00150	-53.2
Bull	2.36	5.82	3.5	0.00320	0.00167	-47.8
Cane(Cook)	1.91	63.9	3	0.00187	0.00060	-68.0
Cane(Cook)	3.25	57.8	5	0.00156	0.00062	-59.9
Cane(Cook)	7.20	48.1	4.5	0.00179	0.00067	-62.3
Cane(Cook)	8.95	40.9	5	0.00208	0.00072	-65.2
Cane(Cook)	9.04	36.0	4	0.00210	0.00076	-63.6
Cane(Cook)	10.70	32.8	4	0.00299	0.00079	-73.5
Cane(Cook)	10.99	30.8	4	0.00300	0.00082	-72.8
Cane(Cook)	11.27	28.3	4	0.00300	0.00085	-71.8
Cane(Cook)	13.27	20.7	4	0.00328	0.00097	-70.4
Dry (Yalobusha)	0.6	53.7	3	0.00367	0.00064	-82.5
Dry (Yalobusha)	3.25	21.9	4	0.00511	0.00095	-81.5
Dry (Topashaw)	2.30	65.8	4	0.00258	0.00059	-77.2
Dry (Topashaw)	3.22	65.4	4	0.00310	0.00059	-81.0
Dry (Topashaw)	5.01	61.2	3.5	0.00414	0.00061	-85.3
Duncan	2.37	18.5	5	0.00195	0.00102	-47.9
Duncan	5.64	12.7	4	0.00217	0.00120	-44.8
Duncan	8.94	7.80	4	0.00296	0.00147	-50.1
Gordon	1.27	29.0	3	0.00129	0.00084	-34.9
Gordon	4.90	47.8	3	0.00189	0.00068	-64.2
Huffman	1.90	21.9	5	0.00170	0.00095	-44.3
Huffman	4.51	16.3	3.5	0.00225	0.00107	-52.2
Huffman T 1	0.90	9.72	3.5	0.00362	0.00134	-62.9
Huffman T 1	2.15	8.59	4	-	0.00141	-
Hurricane	2.80	5.51	3.5	0.00292	0.00171	-41.5
Hurricane	5.58	14.4	5	0.00140	0.00113	-19.2
Hurricane	7.78	11.9	5	0.00228	0.00123	-46.2
Hurricane	7.78	11.9	4	0.00230	0.00123	-46.6
Johnson	0.15	22.0	4	0.00472	0.00094	-80.0
Johnson	0.68	21.9	4	0.00470	0.00094	-79.9
Johnson	0.96	21.9	3	0.00470	0.00095	-79.9
Johnson	1.21	15.9	3	0.00169	0.00109	-35.6
Johnson	4.18	7.91	3	0.00225	0.00146	-34.8
Johnson T 1	1.80	2.23	4	-	0.00252	-
L Topashaw	0.78	68.8	4	0.00208	0.00058	-72.2
L Topashaw	3.15	56.3	4	0.00210	0.00063	-70.0
L Topashaw	4.50	21.5	4	0.00210	0.00095	-54.6
L Topashaw	9.40	5.90	3	0.00335	0.00166	-50.4
L Topashaw	11.00	2.47	3	0.00330	0.00242	-26.8
L Topashaw T1	0.63	54.2	5	0.00340	0.00064	-81.1

Table 6--Predicted stable slopes for reaches currently (1997) in stage III, IV, or V using stage VI stable-slope relation (equation 1; See Figure 13).

Stream	River Kilometer	Drainage Area (km^2)	Stage	Observed Slope	Predicted Equilibrium Slope	Difference (%)
L Topashaw T1	2.84	27.7	4	0.00340	0.00086	-74.8
L. Topashaw T-2	0.29	6.68	3	0.00354	0.00158	-55.5
L. Topashaw T-2	1.39	2.13	3	0.00354	0.00257	-27.2
Lick	6.72	37.8	3	0.00321	0.00075	-76.7
Meridian	5.88	22.0	5	0.00213	0.00094	-55.7
Meridian	8.20	14.9	3	0.00221	0.00112	-49.5
Meridian	9.24	11.6	3	0.00220	0.00124	-43.5
Meridian	10.11	5.47	3	0.00399	0.00172	-57.0
Meridian T 1	10.16	4.40	3	-	0.00189	-
Meridian T 1	11.22	2.84	3	-	0.00228	-
Meridian T 1	12.11	1.99	3	-	0.00265	-
Miles	1.11	15.3	3	0.00236	0.00110	-53.2
Mud	1.95	35.7	4	0.00170	0.00077	-55.0
Mud	2.15	26.0	4	0.00196	0.00088	-55.3
Mud	2.32	26.0	3	0.00200	0.00088	-56.1
Mud	3.31	23.6	3	0.00141	0.00092	-35.2
Mud	5.79	26.9	3	0.00087	0.00087	-0.5
Mud	7.66	23.6	3	0.00082	0.00092	12.3
Mud	10.60	18.3	3	0.00142	0.00102	-28.1
Mud	14.60	8.28	3	0.00234	0.00144	-38.6
Mud T 1	1.41	58.5	3	0.00260	0.00062	-76.2
Mud T 3	0.47	0.50	3	0.00460	0.00480	4.4
N. Topashaw	0.25	25.2	5	0.00230	0.00089	-61.3
N. Topashaw	1.45	24.2	4	0.00230	0.00091	-60.6
N. Topashaw	4.16	13.8	3	0.00381	0.00115	-69.7
N. Topashaw	4.41	13.7	3	0.00380	0.00116	-69.6
N. Topashaw T 1	0.92	0.64	3	0.00939	0.00432	-54.0
N. Topashaw T 2	1.29	4.75	3	0.00409	0.00182	-55.4
Naron	0.01	21.7	4	0.00274	0.00095	-65.3
Naron	0.14	21.7	3	0.00270	0.00095	-64.8
Naron	6.78	21.5	3	-	0.00095	-
Naron	11.30	9.26	3	-	0.00137	-
Splunge	2.59	11.6	5	0.00140	0.00124	-11.2
Splunge	4.08	10.5	4	0.00181	0.00130	-28.3
Splunge	4.48	8.20	4	-	0.00144	-
Splunge	4.56	8.20	3	-	0.00144	-
Topashaw	9.97	248	5	0.00046	0.00033	-27.1
Topashaw	12.70	232	5	0.00054	0.00034	-36.6
Topashaw	13.90	173	5	0.00050	0.00039	-22.3
Topashaw	17.60	138	5	0.00079	0.00043	-45.6
Topashaw	20.60	124	5	0.00177	0.00045	-74.6
Topashaw	23.60	22.9	5	0.00180	0.00093	-48.5
Topashaw	26.10	19.6	4	0.00305	0.00099	-67.5
Topashaw	27.10	15.1	4	0.00310	0.00111	-64.2
Topashaw	28.90	8.08	4	0.00428	0.00145	-66.1
Topashaw	29.80	2.48	3.5	0.00430	0.00241	-43.9
Topashaw T 1	2.07	12.7	4	0.00280	0.00120	-57.2
Topashaw T 1	3.49	8.80	3.5	0.00225	0.00140	-37.9
Topashaw T 2	2.77	2.90	3	0.00371	0.00226	-39.3
Topashaw T 3	0.12	18.4	4	0.00910	0.00102	-88.8
Topashaw T 3	0.75	18.2	3	0.00910	0.00102	-88.7
Topashaw T 4	0.13	11.6	4	0.00683	0.00124	-81.8
Topashaw T 4	1.99	9.73	3	0.00680	0.00134	-80.3
Twin	11.35	5.00	3	0.00378	0.00178	-52.8
Walnut	0.07	24.9	4	0.00314	0.00089	-71.5
Walnut	2.59	14.6	4	0.00310	0.00113	-63.7
Walnut	4.68	4.20	4	0.00376	0.00192	-48.8
Yalobusha	17.84	379	5	-	0.00028	-
Yalobusha	25.00	248	5	0.00046	0.00033	-26.8
Yalobusha	25.70	230	5	0.00045	0.00034	-24.3
Yalobusha	27.20	218	5	0.00101	0.00035	-65.3
Yalobusha	28.30	139	5	0.00102	0.00043	-58.0
Yalobusha	28.60	139	4.5	0.00102	0.00043	-58.2
Yalobusha	28.80	139	3.5	0.00103	0.00043	-58.4
Yalobusha	32.90	103	3	0.00103	0.00049	-52.9
Yalobusha	33.40	103	3	0.00056	0.00049	-12.8
Yalobusha	33.50	102	3	0.00056	0.00049	-12.5
Yalobusha	34.80	75.7	3.5	0.00056	0.00055	-0.5
Yalobusha T 1	2.73	14.7	3	0.00056	0.00112	100.8
Yalobusha T 2	2.02	8.92	3	0.00198	0.00139	-29.6
Yalobusha T 2	4.36	2.90	4	0.00107	0.00226	110.4
					Mean =	**-48.8**

Table 7--Predicted stable slopes for reaches currently (1997) in stage III, IV, or V using the modified stage VI stable-slope relation (equation 2; See Figure 13).

Stream	River Kilometer	Drainage Area (km^2)	Stage	Observed Slope	Predicted Equilibrium Slope	Difference (%)
Anderson	1.37	10.0	3	0.00470	0.00131	-72.2
Bear	0.86	48.5	5	0.00111	0.00078	-30.1
Bear	1.40	48.3	5	0.00132	0.00078	-41.0
Bear	3.50	48.0	5	0.00166	0.00078	-52.9
Bear	5.45	34.6	5	0.00266	0.00087	-67.4
Bear	6.25	33.9	4	0.00270	0.00087	-67.6
Bear	8.50	24.7	4	0.00556	0.00097	-82.5
Bear	9.24	14.9	3	0.00213	0.00115	-46.1
Bear	10.84	12.8	3	0.00253	0.00121	-52.4
Bear	13.20	4.16	3	0.00347	0.00175	-49.7
Bear T 2	1.74	41.8	4	0.00397	0.00082	-79.4
Bear T 3	1.03	28.2	3	0.00280	0.00093	-66.8
Bear T 4	0.54	22.8	3	0.00447	0.00100	-77.7
Big	1.92	34.9	5	0.00120	0.00087	-27.9
Big	2.79	34.0	5	0.00097	0.00087	-10.1
Big	3	33.8	5	0.00100	0.00087	-12.5
Big	4.5	33.0	4	0.00097	0.00088	-8.9
Big	5.75	30.0	5	0.00138	0.00091	-34.0
Big	6.24	23.3	5	0.00140	0.00099	-29.3
Big	6.40	22.0	4	0.00140	0.00101	-28.0
Big	6.80	21.8	5	0.00051	0.00101	99.4
Big	7.73	19.2	5	0.00141	0.00105	-25.0
Big	8.21	17.0	5	0.00140	0.00110	-21.6
Big	8.38	16.1	4.5	0.00140	0.00112	-20.1
Big	10.77	6.17	3	-	0.00153	-
Big	15.69	4.37	3	-	0.00172	-
Buck	1.31	20.2	4	0.00351	0.00104	-70.4
Buck	3.14	20.1	4	0.00281	0.00104	-63.0
Buck	4.14	19.8	3	0.00280	0.00104	-62.7
Buck	5.01	18.2	3	0.00169	0.00107	-36.5
Buck	9.54	11.2	3	0.00209	0.00126	-39.6
Buck	13.10	4.10	3	0.00308	0.00175	-42.9
Bull	1.1	8.60	4	0.00321	0.00137	-57.1
Bull	1.9	7.72	4	0.00324	0.00142	-56.0
Bull	2.04	7.51	3.5	0.00320	0.00144	-55.1
Bull	2.36	5.82	3.5	0.00320	0.00156	-51.2
Cane(Cook)	1.91	63.9	3	0.00187	0.00071	-62.0
Cane(Cook)	3.25	57.8	5	0.00156	0.00073	-52.9
Cane(Cook)	7.20	48.1	4.5	0.00179	0.00078	-56.5
Cane(Cook)	8.95	40.9	5	0.00208	0.00082	-60.5
Cane(Cook)	9.04	36.0	4	0.00210	0.00086	-59.2
Cane(Cook)	10.70	32.8	4	0.00299	0.00088	-70.5
Cane(Cook)	10.99	30.8	4	0.00300	0.00090	-69.9
Cane(Cook)	11.27	28.3	4	0.00300	0.00093	-69.1
Cane(Cook)	13.27	20.7	4	0.00328	0.00103	-68.6
Dry (Yalobusha)	0.6	53.7	3	0.00367	0.00075	-79.5
Dry (Yalobusha)	3.25	21.9	4	0.00511	0.00101	-80.2
Dry (Topashaw)	2.30	65.8	4	0.00258	0.00070	-72.8
Dry (Topashaw)	3.22	65.4	4	0.00310	0.00070	-77.3
Dry (Topashaw)	5.01	61.2	3.5	0.00414	0.00072	-82.6
Duncan	2.37	18.5	5	0.00195	0.00107	-45.3
Duncan	5.64	12.7	4	0.00217	0.00121	-44.2
Duncan	8.94	7.80	4	0.00296	0.00142	-52.0
Gordon	1.27	29.0	3	0.00129	0.00092	-28.5
Gordon	4.90	47.8	3	0.00189	0.00078	-58.6
Huffman	1.90	21.9	5	0.00170	0.00101	-40.5
Huffman	4.51	16.3	3.5	0.00225	0.00111	-50.5
Huffman T 1	0.90	9.72	3.5	0.00362	0.00132	-63.5
Huffman T 1	2.15	8.59	4	-	0.00137	-
Hurricane	2.80	5.51	3.5	0.00292	0.00159	-45.6
Hurricane	5.58	14.4	5	0.00140	0.00116	-17.2
Hurricane	7.78	11.9	5	0.00228	0.00123	-45.9
Hurricane	7.78	11.9	4	0.00230	0.00123	-46.4
Johnson	0.15	22.0	4	0.00472	0.00101	-78.6
Johnson	0.68	21.9	4	0.00470	0.00101	-78.5
Johnson	0.96	21.9	3	0.00470	0.00101	-78.5
Johnson	1.21	15.9	3	0.00169	0.00112	-33.4
Johnson	4.18	7.91	3	0.00225	0.00141	-37.1
Johnson T 1	1.80	2.23	4	-	0.00214	-
L Topashaw	0.78	68.8	4	0.00208	0.00069	-66.7
L Topashaw	3.15	56.3	4	0.00210	0.00074	-64.8
L Topashaw	4.50	21.5	4	0.00210	0.00102	-51.6
L Topashaw	9.40	5.90	3	0.00335	0.00156	-53.5
L Topashaw	11.00	2.47	3	0.00330	0.00207	-37.2
L Topashaw T1	0.63	54.2	5	0.00340	0.00075	-78.0
L Topashaw T1	2.84	27.7	4	0.00340	0.00093	-72.5
L. Topashaw T-2	0.29	6.68	3	0.00354	0.00149	-57.8
L. Topashaw T-2	1.39	2.13	3	0.00354	0.00218	-38.5
Lick	6.72	37.8	3	0.00321	0.00084	-73.7
Meridian	5.88	22.0	5	0.00213	0.00101	-52.7
Meridian	8.20	14.9	3	0.00221	0.00115	-48.2
Meridian	9.24	11.6	3	0.00220	0.00124	-43.4
Meridian	10.11	5.47	3	0.00399	0.00160	-60.0
Meridian T 1	10.16	4.40	3	-	0.00171	-
Meridian T 1	11.22	2.84	3	-	0.00198	-
Meridian T 1	12.11	1.99	3	-	0.00223	-
Miles	1.11	15.3	3	0.00236	0.00114	-51.8
Mud	1.95	35.7	4	0.00170	0.00086	-49.6
Mud	2.15	26.0	4	0.00196	0.00095	-51.4
Mud	2.32	26.0	3	0.00200	0.00095	-52.3
Mud	3.31	23.6	3	0.00141	0.00099	-30.3
Mud	5.79	26.9	3	0.00087	0.00094	8.5
Mud	7.66	23.6	3	0.00082	0.00099	20.8
Mud	10.60	18.3	3	0.00142	0.00107	-24.6
Mud	14.60	8.28	3	0.00234	0.00139	-40.5
Mud T 1	1.41	58.5	3	0.00260	0.00073	-71.9
Mud T 3	0.47	0.50	3	0.00460	0.00351	-23.7
N. Topashaw	0.25	25.2	5	0.00230	0.00096	-58.1
N. Topashaw	1.45	24.2	4	0.00230	0.00098	-57.5
N. Topashaw	4.16	13.8	3	0.00381	0.00118	-69.1
N. Topashaw	4.41	13.7	3	0.00380	0.00118	-69.0
N. Topashaw T 1	0.92	0.64	3	0.00939	0.00324	-65.5

Table 7--Predicted stable slopes for reaches currently (1997) in stage III, IV, or V using the modified stage VI stable-slope relation (equation 2; See Figure 13).

Stream	River Kilometer	Drainage Area (km^2)	Stage	Observed Slope	Predicted Equilibrium Slope	Difference (%)
N. Topashaw T 2	1.29	4.75	3	0.00409	0.00167	-59.1
Naron	0.01	21.7	4	0.00274	0.00101	-63.0
Naron	0.14	21.7	3	0.00270	0.00101	-62.5
Naron	6.78	21.5	3	-	0.00102	-
Naron	11.30	9.26	3	-	0.00134	-
Splunge	2.59	11.6	5	0.00140	0.00124	-11.1
Splunge	4.08	10.5	4	0.00181	0.00129	-28.8
Splunge	4.48	8.20	4	-	0.00140	-
Splunge	4.56	8.20	3	-	0.00140	-
Topashaw	9.97	248	5	0.00046	0.00045	-0.8
Topashaw	12.70	232	5	0.00054	0.00046	-14.2
Topashaw	13.90	173	5	0.00050	0.00051	2.1
Topashaw	17.60	138	5	0.00079	0.00055	-30.2
Topashaw	20.60	124	5	0.00177	0.00057	-67.8
Topashaw	23.60	22.9	5	0.00180	0.00099	-44.8
Topashaw	26.10	19.6	4	0.00305	0.00105	-65.7
Topashaw	27.10	15.1	4	0.00310	0.00114	-63.2
Topashaw	28.90	8.08	4	0.00428	0.00140	-67.2
Topashaw	29.80	2.48	3.5	0.00430	0.00207	-51.8
Topashaw T 1	2.07	12.7	4	0.00280	0.00121	-56.8
Topashaw T 1	3.49	8.80	3.5	0.00225	0.00136	-39.5
Topashaw T 2	2.77	2.90	3	0.00371	0.00197	-47.0
Topashaw T 3	0.12	18.4	4	0.00910	0.00107	-88.3
Topashaw T 3	0.75	18.2	3	0.00910	0.00107	-88.2
Topashaw T 4	0.13	11.6	4	0.00683	0.00124	-81.8
Topashaw T 4	1.99	9.73	3	0.00680	0.00132	-80.6
Twin	11.35	5.00	3	0.00378	0.00164	-56.5
Walnut	0.07	24.9	4	0.00314	0.00097	-69.2
Walnut	2.59	14.6	4	0.00310	0.00115	-62.8
Walnut	4.68	4.20	4	0.00376	0.00174	-53.7
Yalobusha	17.84	379	5	-	0.00039	-
Yalobusha	25.00	248	5	0.00046	0.00045	-0.4
Yalobusha	25.70	230	5	0.00045	0.00046	2.3
Yalobusha	27.20	218	5	0.00101	0.00047	-53.4
Yalobusha	28.30	139	5	0.00102	0.00055	-46.1
Yalobusha	28.60	139	4.5	0.00102	0.00055	-46.3
Yalobusha	28.80	139	3.5	0.00103	0.00055	-46.5
Yalobusha	32.90	103	3	0.00103	0.00061	-41.2
Yalobusha	33.40	103	3	0.00056	0.00061	8.7
Yalobusha	33.50	102	3	0.00056	0.00061	9.0
Yalobusha	34.80	75.7	3.5	0.00056	0.00067	20.3
Yalobusha T 1	2.73	14.7	3	0.00056	0.00115	106.0
Yalobusha T 2	2.02	8.92	3	0.00198	0.00136	-31.3
Yalobusha T 2	4.36	2.90	4	0.00107	0.00197	83.5
					Mean =	**-45.7**

Evidence of the rate and magnitude of the ongoing aggradation process on the lower ends of the Yalobusha River and Topashaw Creek are further supported by gaging-station data. The elevation of the annual minimum stage is generally a good indicator of long-term changes on the channel bed in the vicinity of the gaging station. In the 30 years since the most recent channel work, the elevation of the annual-minimum stage of the Yalobusha River at the Highway 9 bridge has increased about 1.5 m, with most of the increase taking place since 1980 (Figure 15). For Topashaw Creek, the elevation of the minimum stage has increased about 1 m since 1967, with most of the increase occurring since 1989. Accelerated aggradation has occurred since the peak flows of 1991 (Figure 15). Note that aggradation at both of these sites, and presumably along the rest of the aggrading downstream reaches, has been episodic.

Stage IV Conditions

Channel conditions deteriorate to stage IV indicating a shift to degradation on the channel bed and more rapid channel widening by mass failures on both streams. This occurs about halfway between the Vardaman Bridge (Highway 341) and the confluence of Mud Creek on the Yalobusha River (about river kilometer 28.6). On Topashaw Creek, the transition to stage IV conditions occurs between where Little Topashaw Creek and the west-southwest flowing branch of Topashaw Creek (herein termed North Topashaw Creek) enter the main stem (about river kilometer 22.1). Tributary streams entering in these reaches are also characterized by stage IV conditions and are highly unstable. In the Yalobusha River Basin, the downstream ends of Johnson, Cane, and Mud Creeks are particularly unstable with large, recent bank failures. In the Topashaw Creek Basin, the downstream parts of Buck, Dry, Little Topashaw, and North Topashaw Creeks are particularly unstable (Plate 2).

A comparison of maximum bank heights (as measured as the elevation difference between the top of the bank (or levee if present) to the thalweg from 1967 to 1997 for the Yalobusha River and Topashaw Creek main stems shows the magnitude of channel deepening during the past 31 years and the reason for destabilization of the channel banks.(Figures 16 and 17).

The transition area between stages IV and V has apparently migrated upstream (albeit slowly) because tributaries entering the Yalobusha River and Topashaw Creek downstream from the current transition zones are characterized by stage IV conditions in their middle reaches. These tributaries also have generally greater bank heights through a greater proportion of their lengths (Figures 18-20). Examples of this include Bear Creek in the Topashaw River Basin and Big, Cane, Duncan, Huffman, Hurricane, and Meridian Creeks in the Yalobusha River Basin (Plate 2). Big Creek, which enters the Yalobusha River even further downstream (at river kilometer 4.5) from the current transition zone, and its tributary Rocky Branch, both have major knickzones in their middle reaches in the order of 3 m high. Over a reach of Big Creek between river kilometers 6.5 and 6.8, the channel gradient is about 0.01. Migration of the erosion process along Miles and Splunge Creeks was less, probably because of their smaller drainage areas not providing sufficient stream power frequently enough to erode the resistant clay beds.

Tributaries entering the main stem channels in the vicinity of the current zones of maximum instability show a relatively rapid decrease in bank heights with distance upstream. This is indicative of recently rejuvenated streams where degradation has not had enough time or been sufficient to destabilze banks more than 2-3 km above the mouth. Examples include

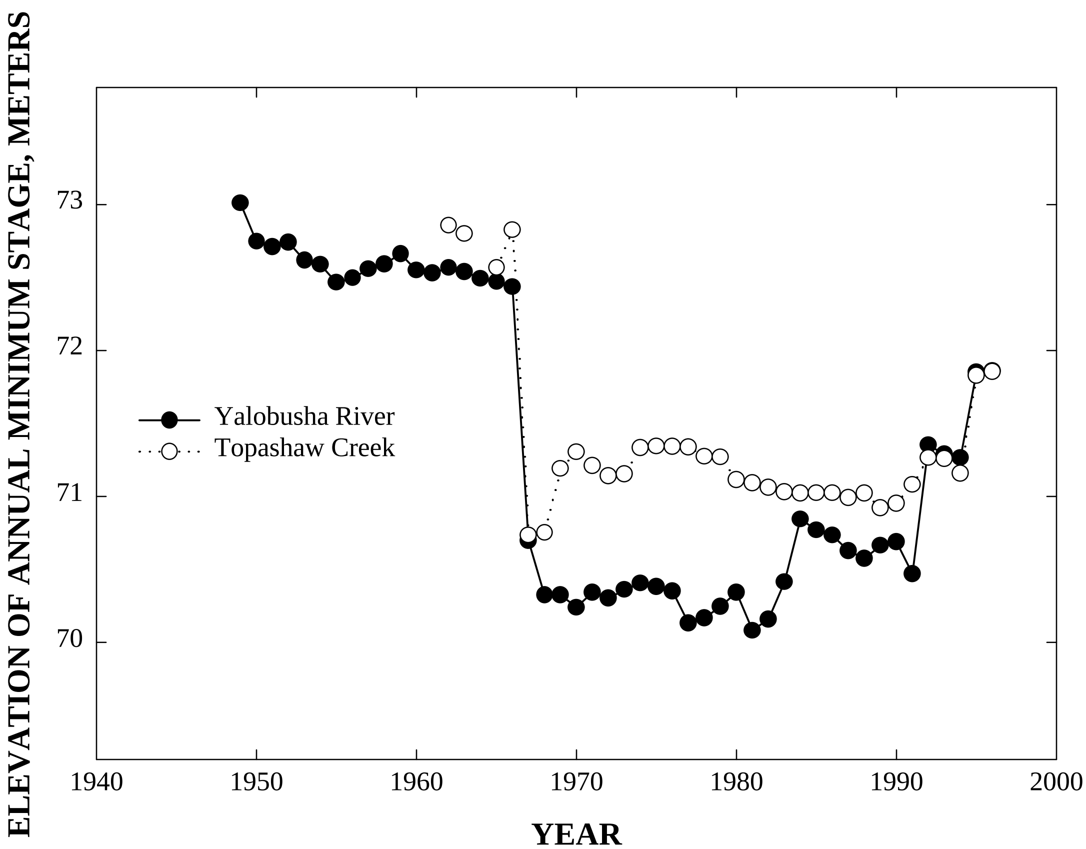


Figure 15--Annual minimum stage of the Yalobusha River at Calhoun City showing amount of and episodic nature of aggradation.

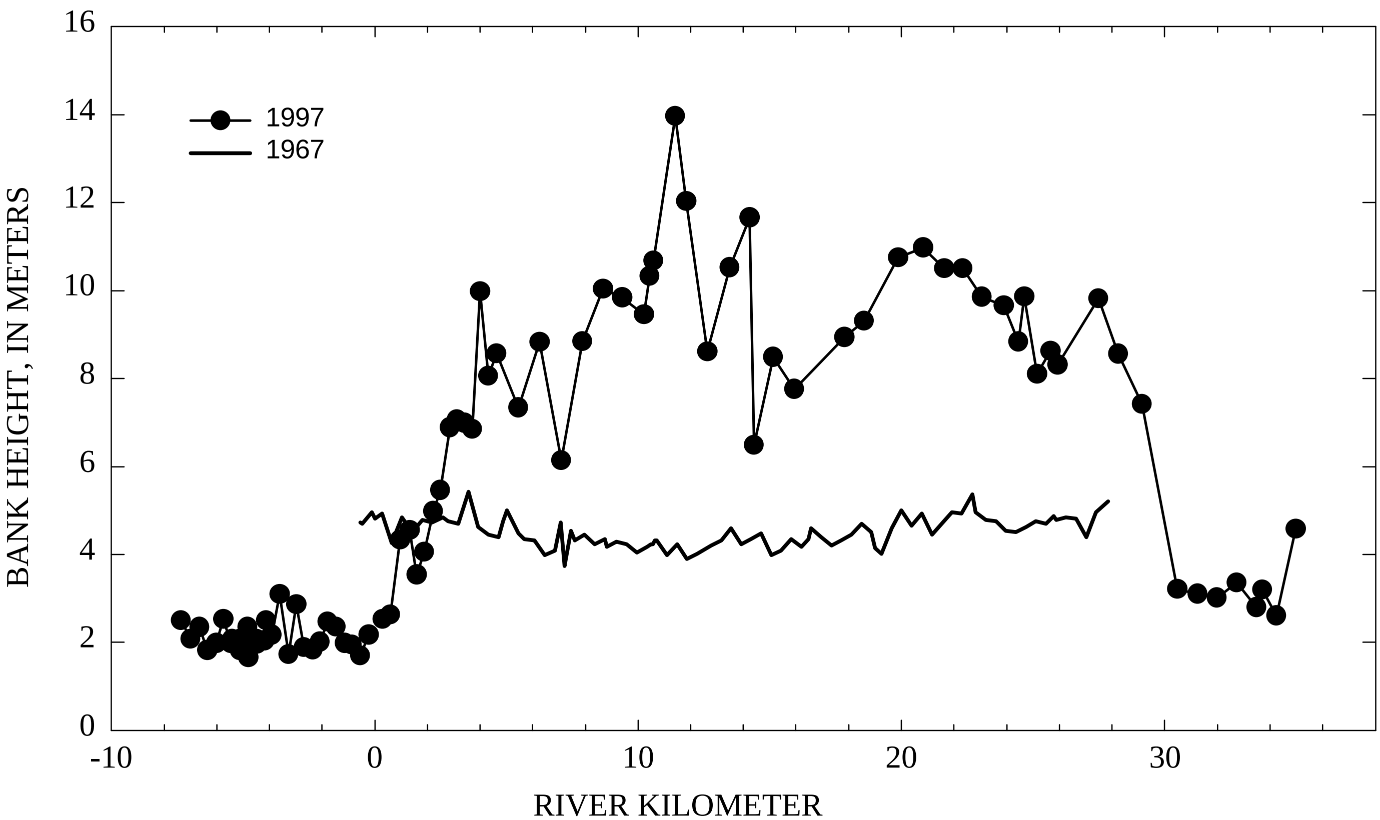


Figure 16--Maximum bank heights along the Yalobusha River main stem for 1967 and 1997.

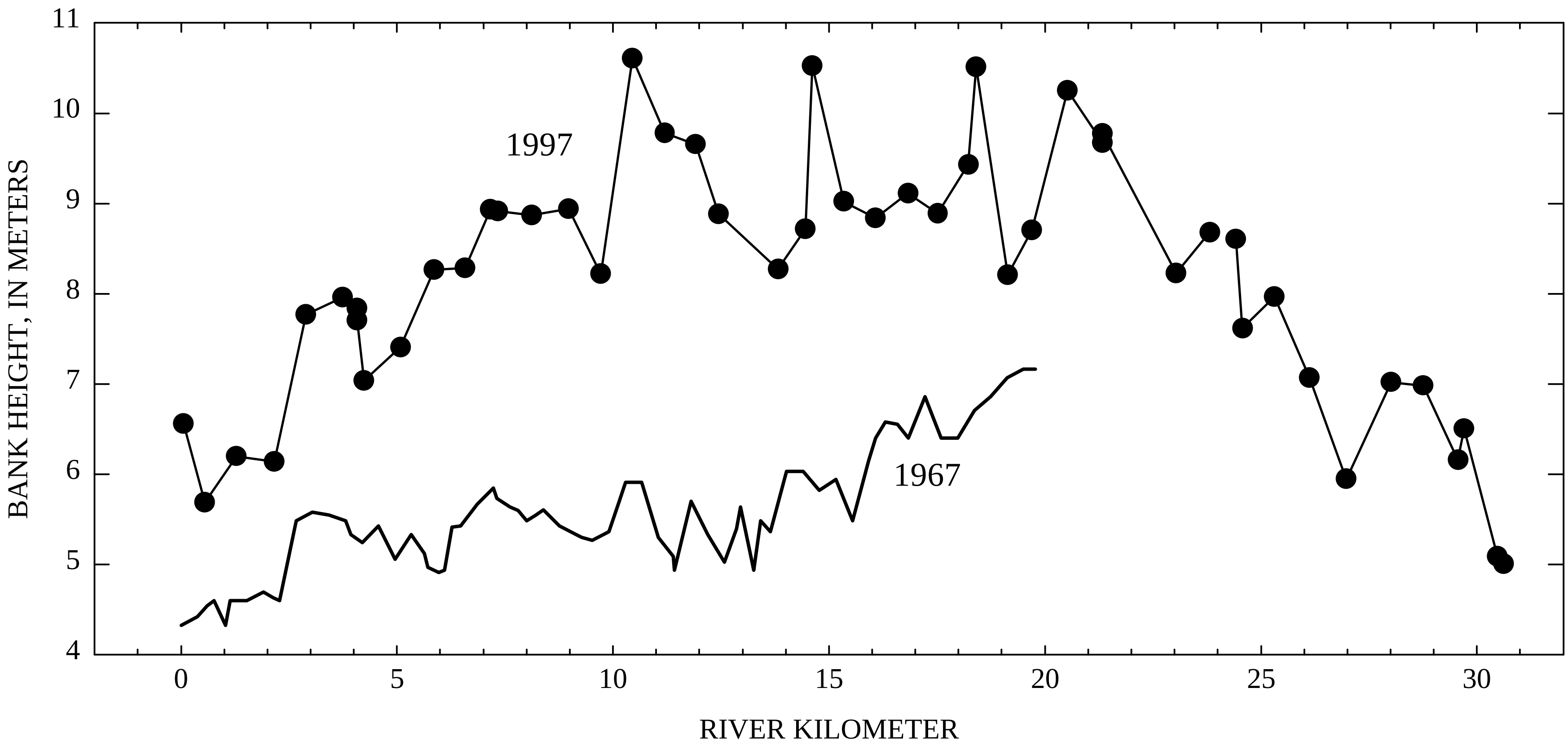


Figure 17--Maximum bank heights along Topashaw Creek for 1967 and 1997.

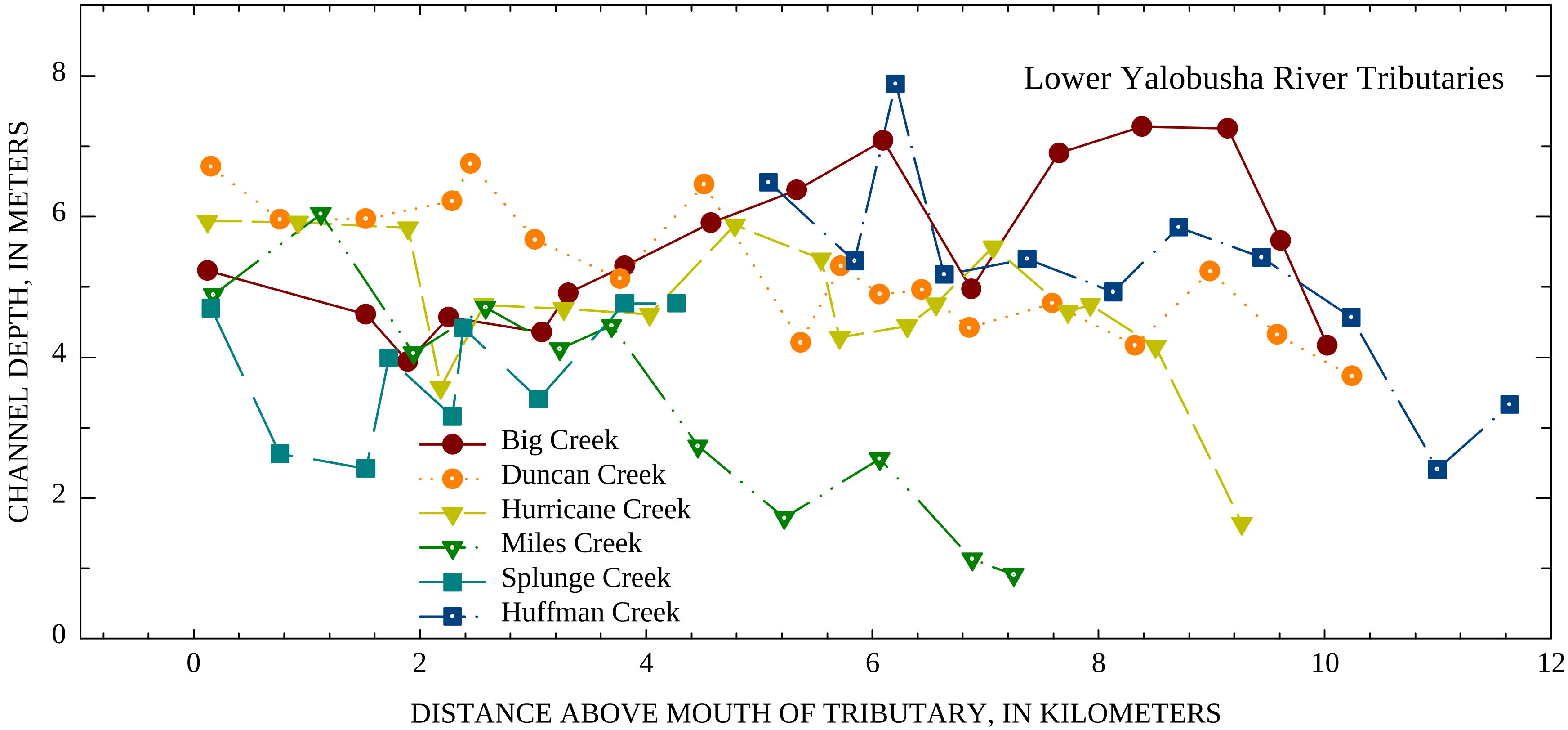


Figure 18--Channel depths of tributaries to the “lower” Yalobusha River.

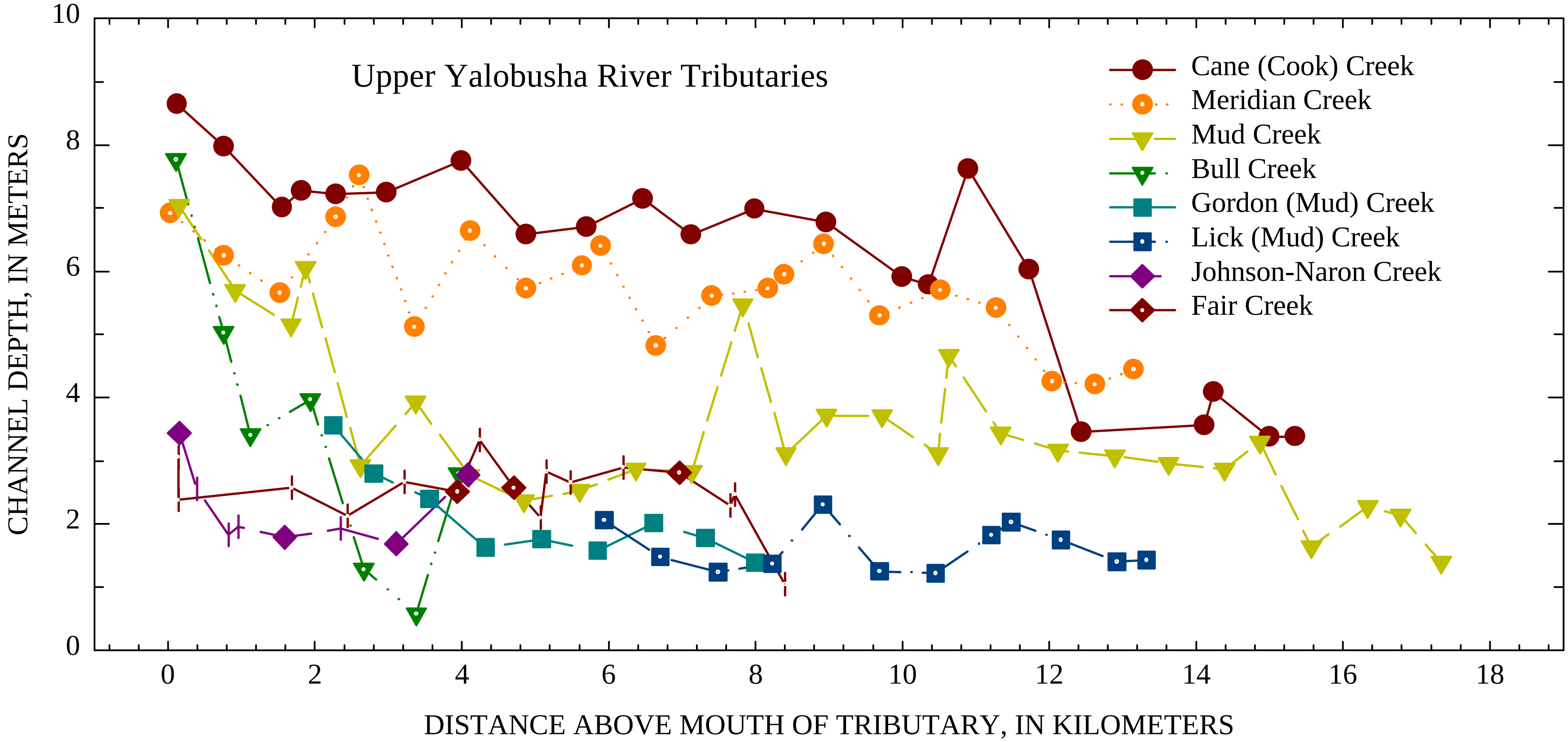


Figure 19--Channel depths of tributaries to the “upper” Yalobusha River.

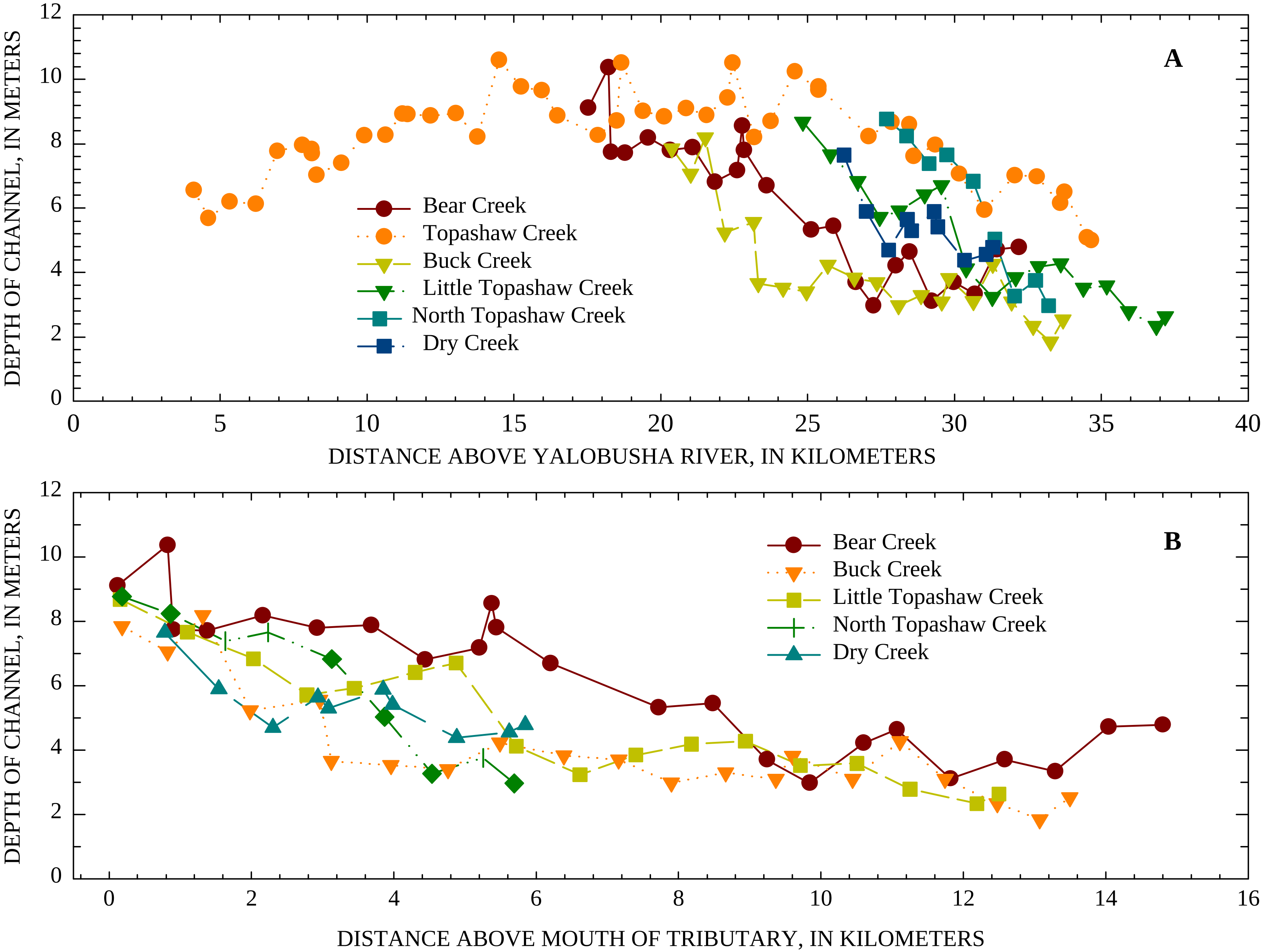


Figure 20--Channel depths of tributaries to Topashaw with distance above the Yalobusha River, showing progression of degradation process (A), and with distance upstream from the mouth of each stream (B).

Bull and Mud Creeks, tributary to the Yalobusha River (Figure 19), and Buck and Dry Creeks, tributary to Topashaw Creek (Figure 20). Grade-control structures placed in the lower reaches of these streams may provide protection from potential destabilization of channel beds and banks upstream. Little Topashaw and North Topashaw Creeks, because of their larger drainage areas contain unstable banks further upstream than the smaller tributaries (to about 6 and 4 km, respectively, above the mouth) (Figure 20).

Frequency and Location of Bank Failures

Banks are unstable and fail by mass-wasting processes during in stages IV and V of the Simon and Hupp (1986) channel evolution model. The occurrence of failures is directly linked to the amount of bed degradation which determines the height of the channel bank and to the steepeness of the bank. Banks on outside bends tend to be steeper because of erosion of bank-toe material by fluvial action. For this reason, outside bends of stage III reaches may show indications of mass-wasting processes and are termed “transition” reaches.

Data on failure frequency were obtained from field inspection by estimating the longitudinal extent of each bank that contained recent bank failures. By combining this data with bank-height data obtained from the 1997 channel surveys, a concise picture of bank-stability conditions over the length of the studied channels was obtained (Figures 21-23). Topashaw Creek provides an excellent example of the relation between the maximum bank height and the amount of the stream reach which is experiencing bank failures (Figure 21). Bank heights increase from about 5.6 to almost 8 m in the downstream-most 7.5 km of Topashaw Creek. However, banks remain stable, in part because of the confining pressure afforded by the backwater in the channel. Bank instabilities begin upstream from this location as bank heights continue to increase beyond 10 m and the backwater effects from the sediment/debris plug decrease. Banks 8-m high in the Yalobusha River which are effected by backwater and confining pressures are also relatively stable (Figure 22 In contrast, 8-m high banks are unstable on Topashaw Creek when backwater effects are not present (such as river kilometers 14 – 17.5; Figure 21).

Failure frequency attains maximum values (close to 100%) along reaches that have only recently become stage IV (basin river-kilometers 21-29). Areas like this throughout the Yalobusha River System represent locations of maximum sediment production and may present opportunities for erosion control. They can be recognized by a rapid decrease in bank heights with increasing distance upstream. Note that bank heights are somewhat lower in these areas because (1) degradation is still occurring, and (2) bank angles have not been reduced by successive failures. The series of figures showing bank height and percent of reach failing can be used, therefore, to identify those reaches where maximum-sediment production is presently occurring (Figures 21-23). Examples include:

1. Bear Creek in the vicinity of and upstream of upstream of rkm 6
2. Big Creek in the vicinity of and upstream of rkm 9
3. Buck Creek in the vicinity of and upstream of rkm 2
4. Bull Creek in the vicinity of and upstream of rkm 2
5. Cane Creek in the vicinity of and upstream of rkm 9
6. Johnson Creek in the vicinity of and upstream of the mouth

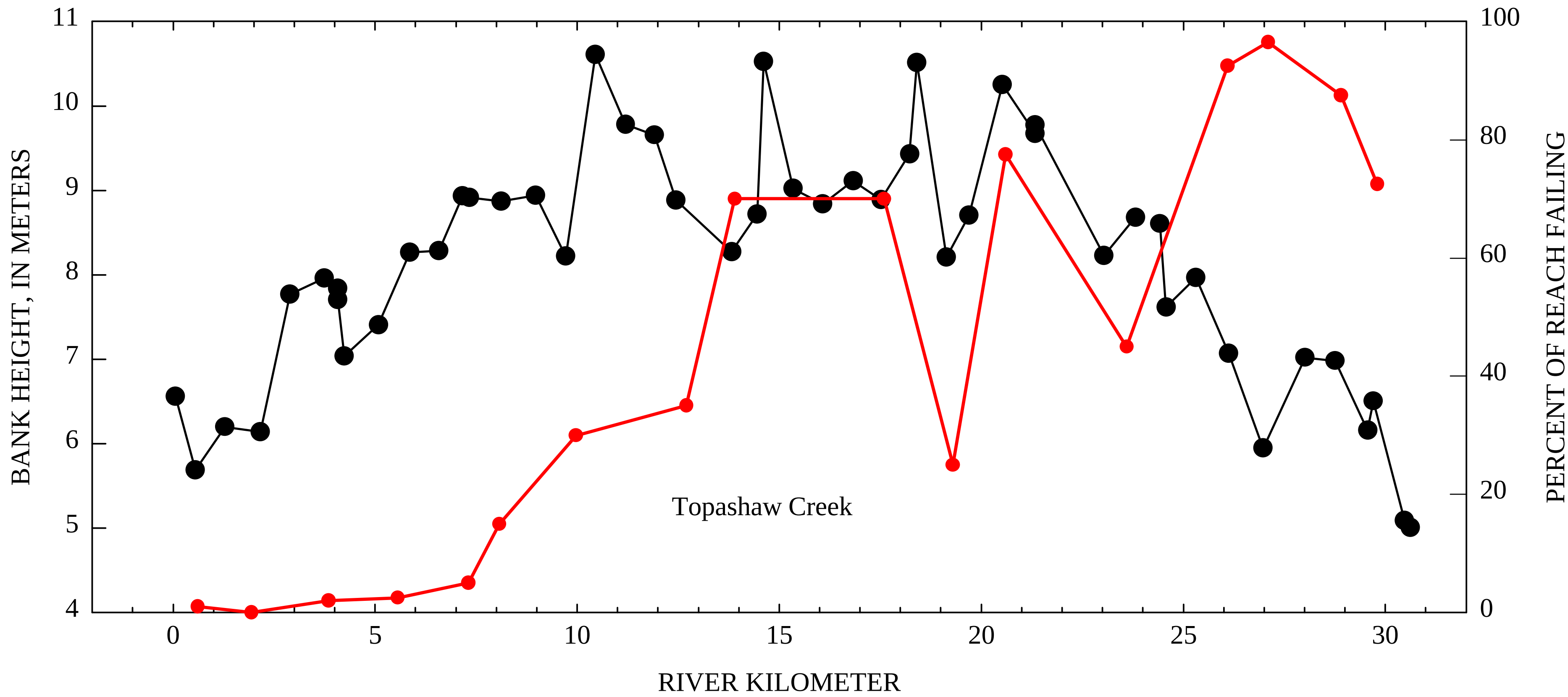


Figure 21--Comparison of maximum bank heights with the percentage of the reach with failing banks for Topashaw Creek.

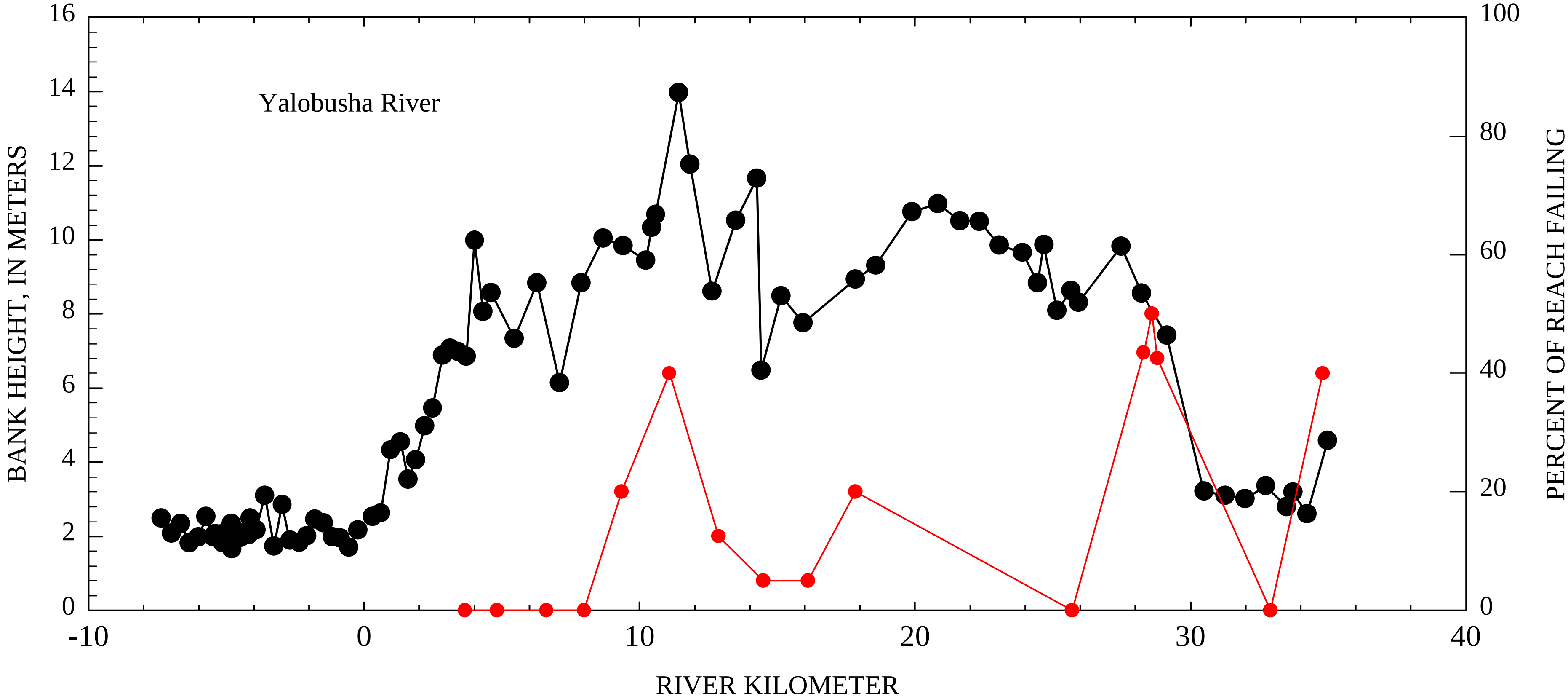


Figure 22--Comparison of maximum bank heights with the percentage of the reach with failing banks for the Yalobusha River.

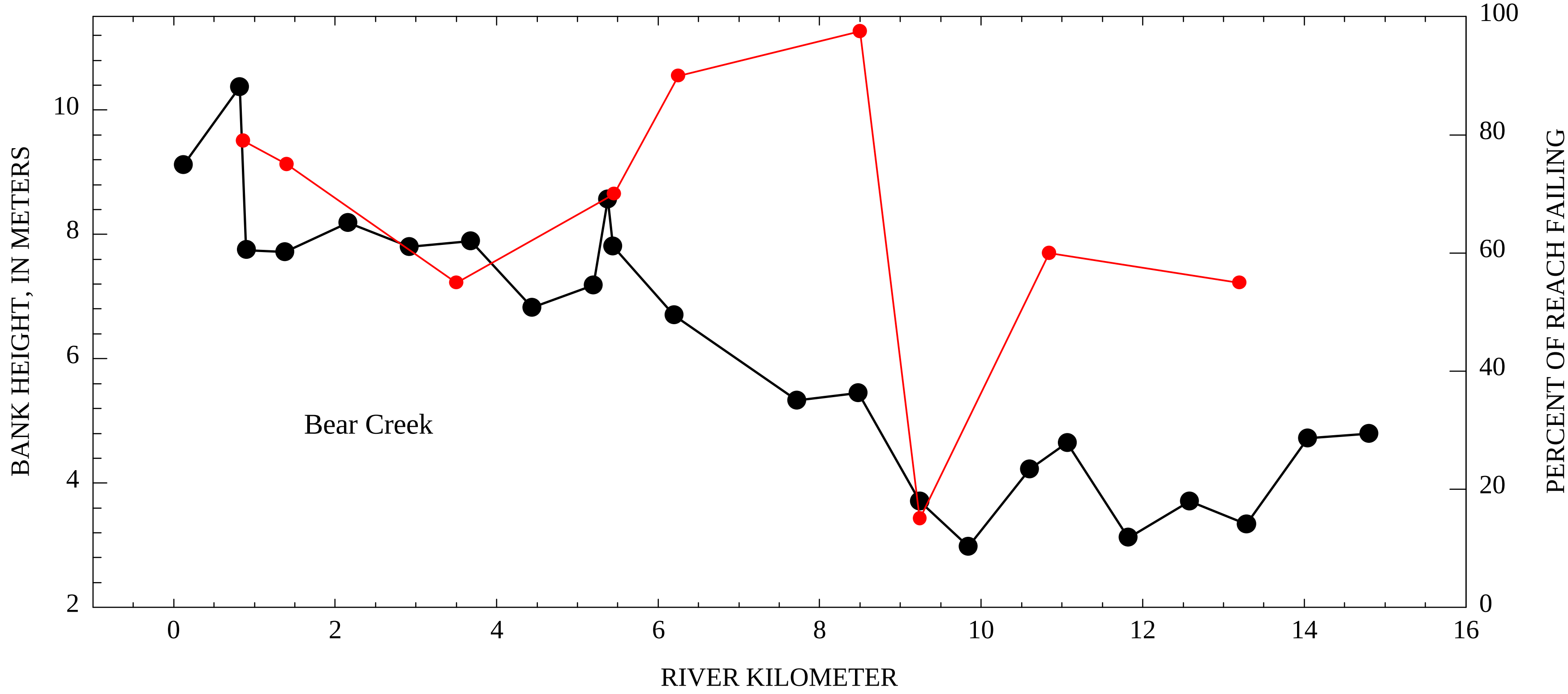


Figure 23A--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

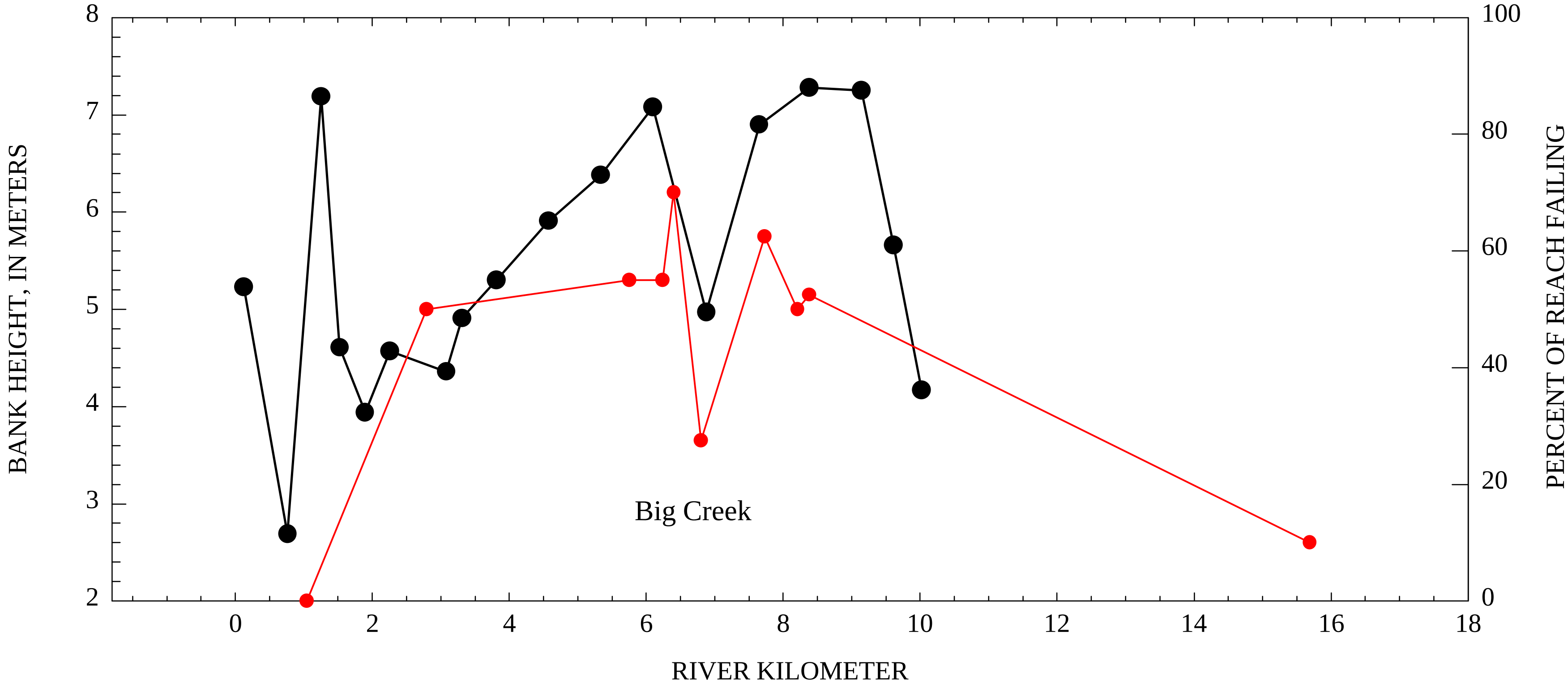


Figure 23B--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

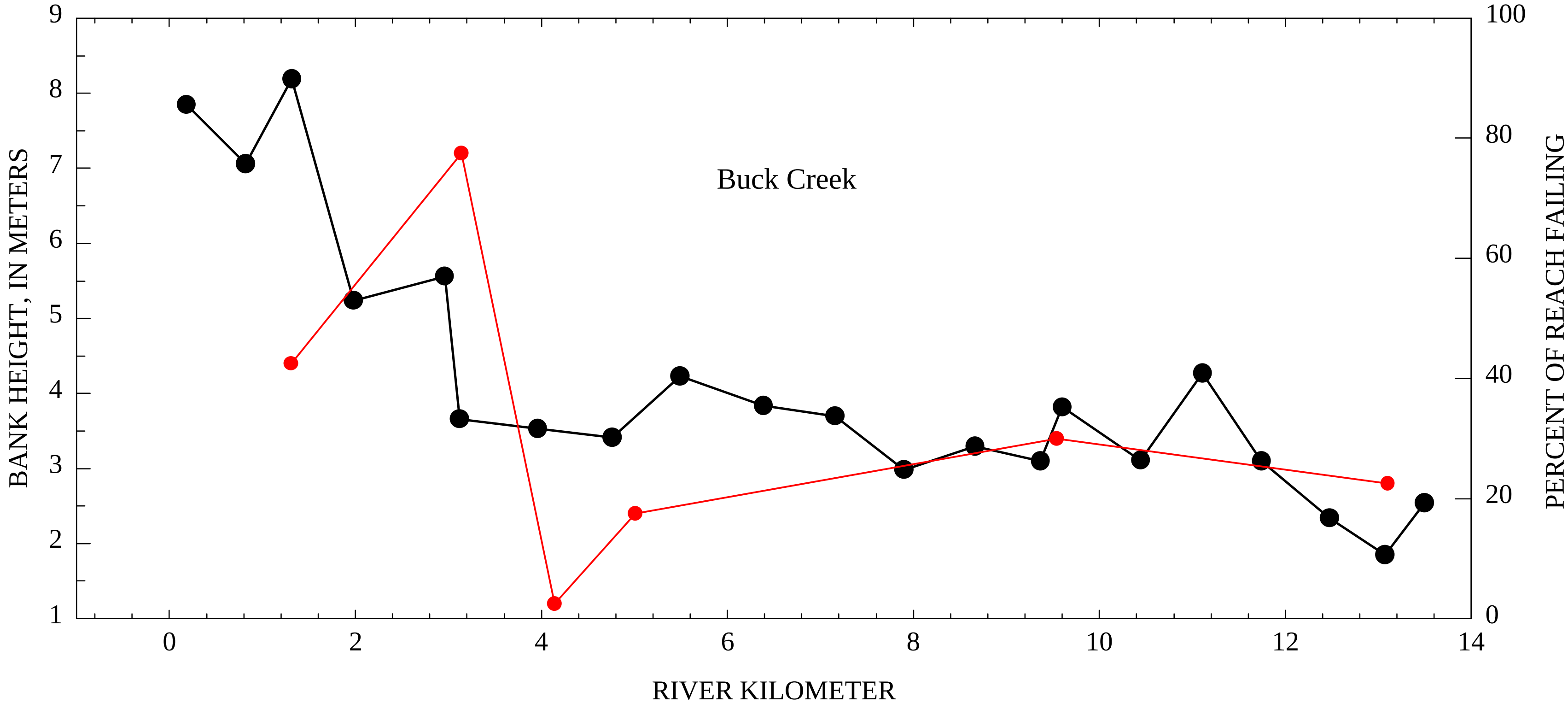


Figure 23C--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

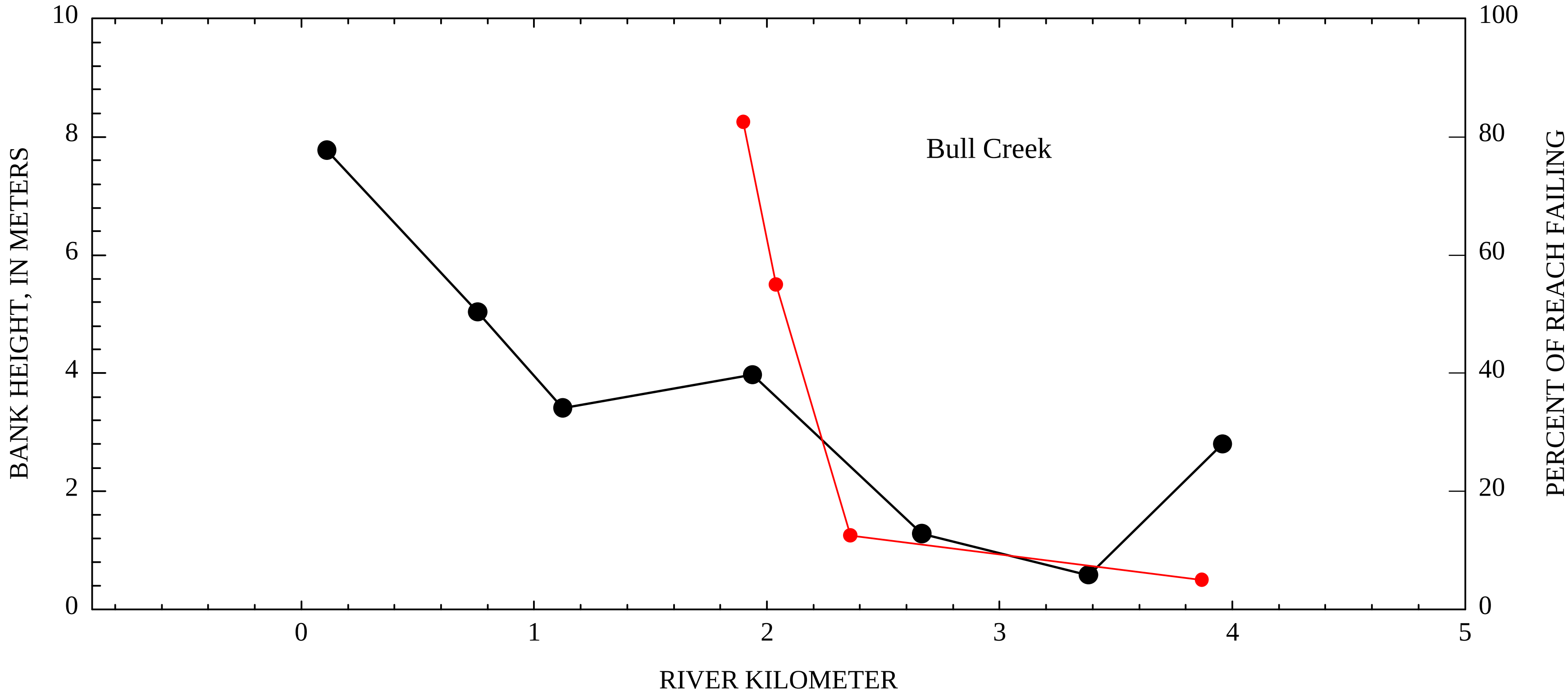


Figure 23D--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

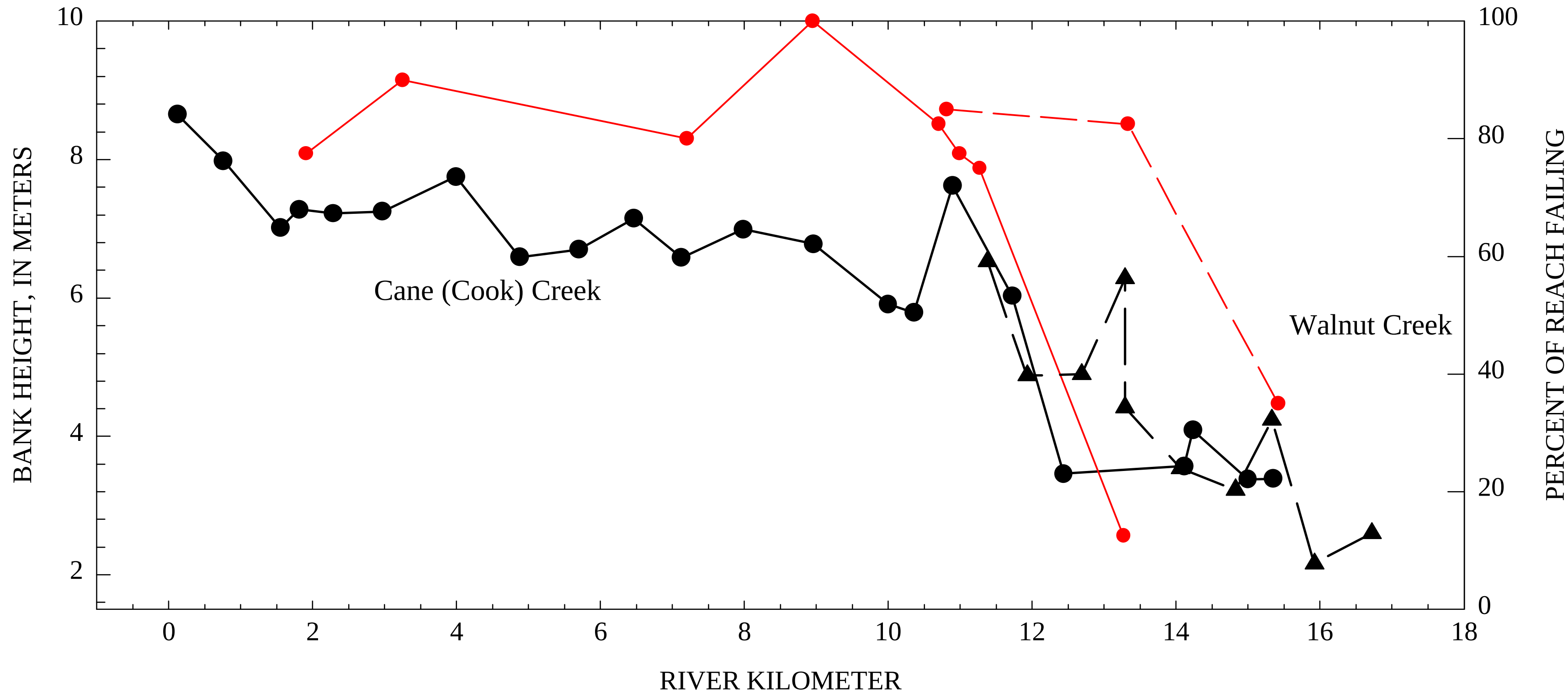


Figure 23E--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

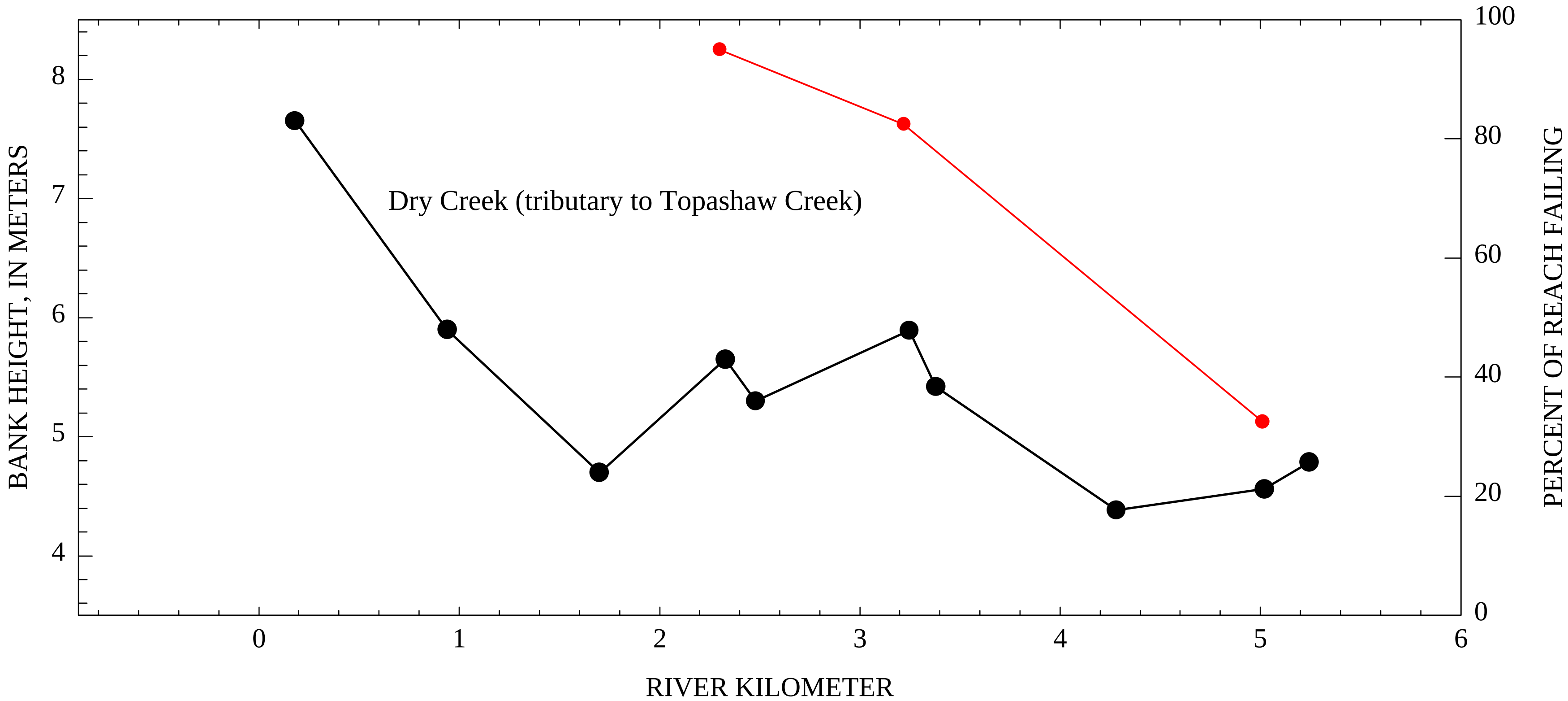


Figure 23F--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

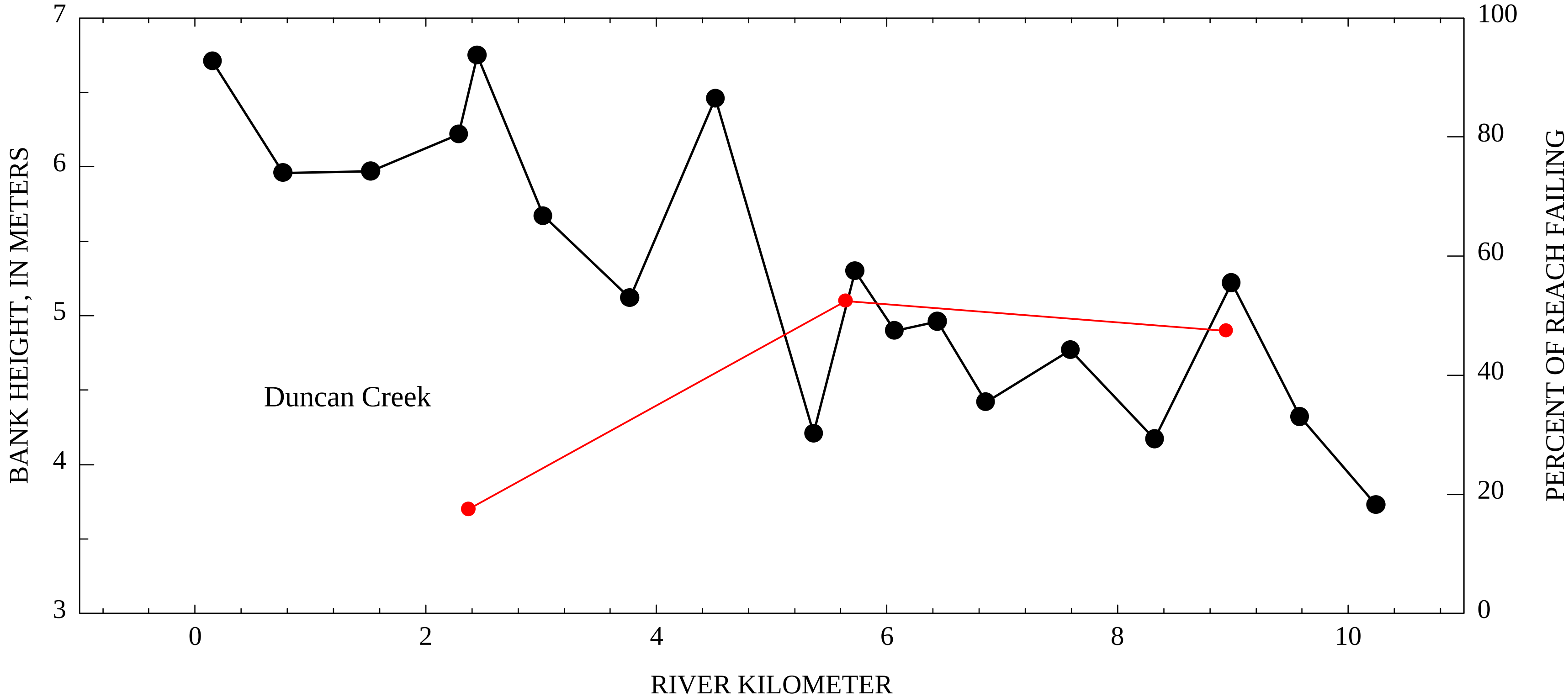


Figure 23G--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

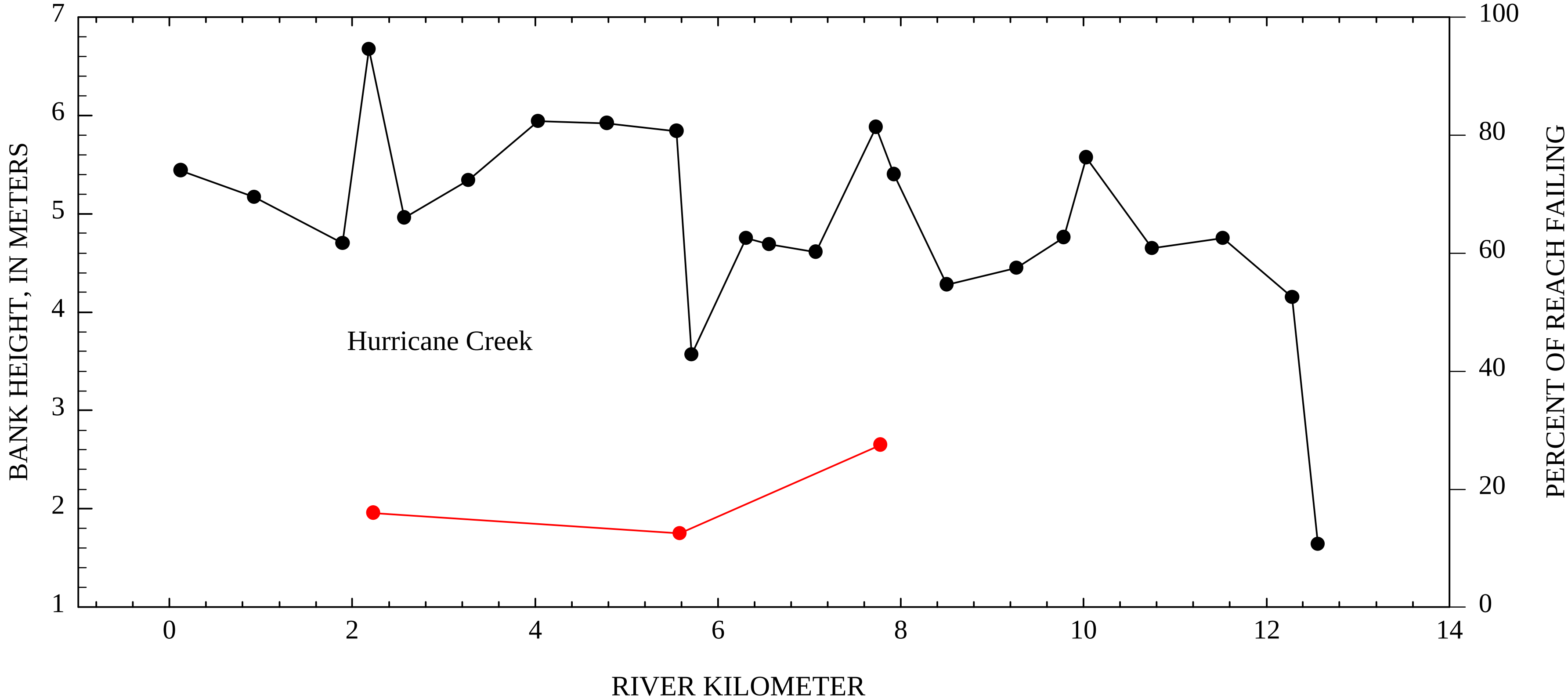


Figure 23H--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

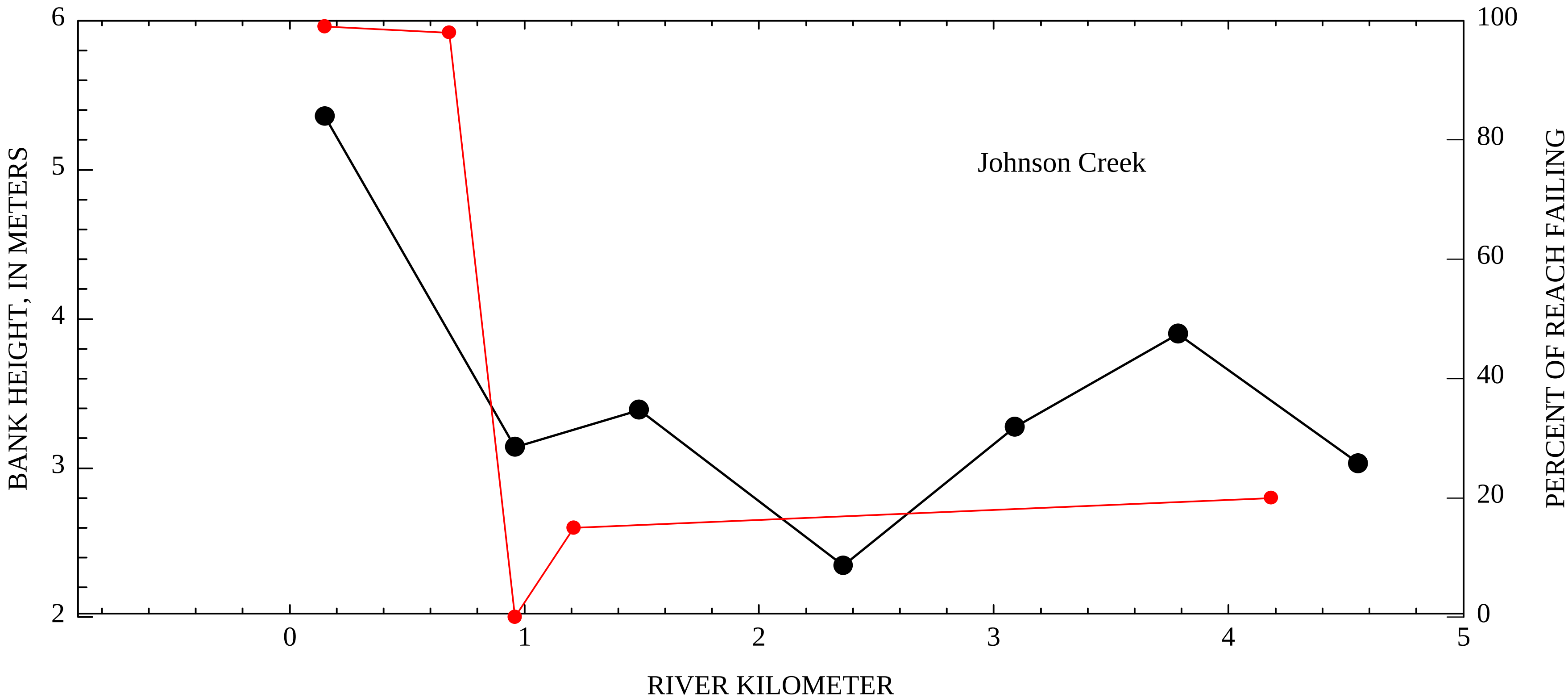


Figure 23I--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

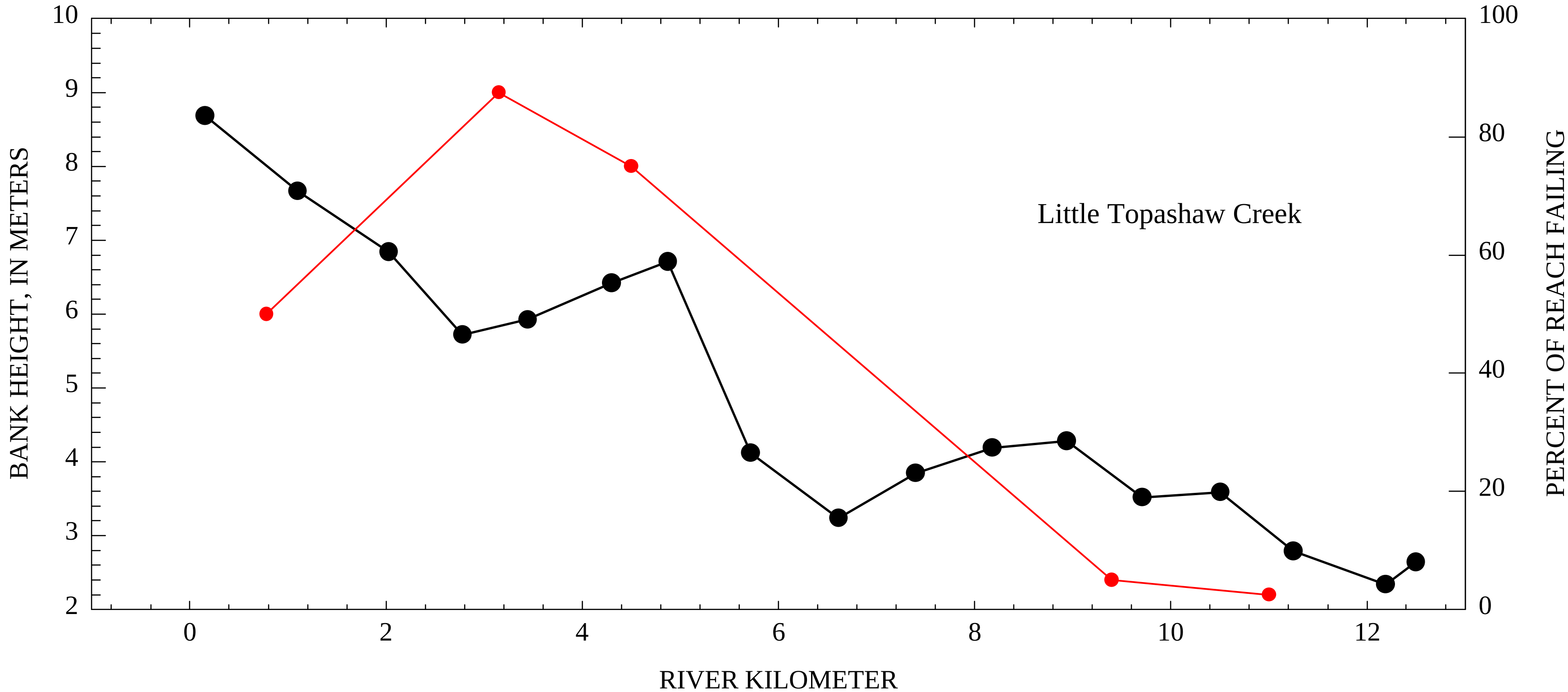


Figure 23J--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

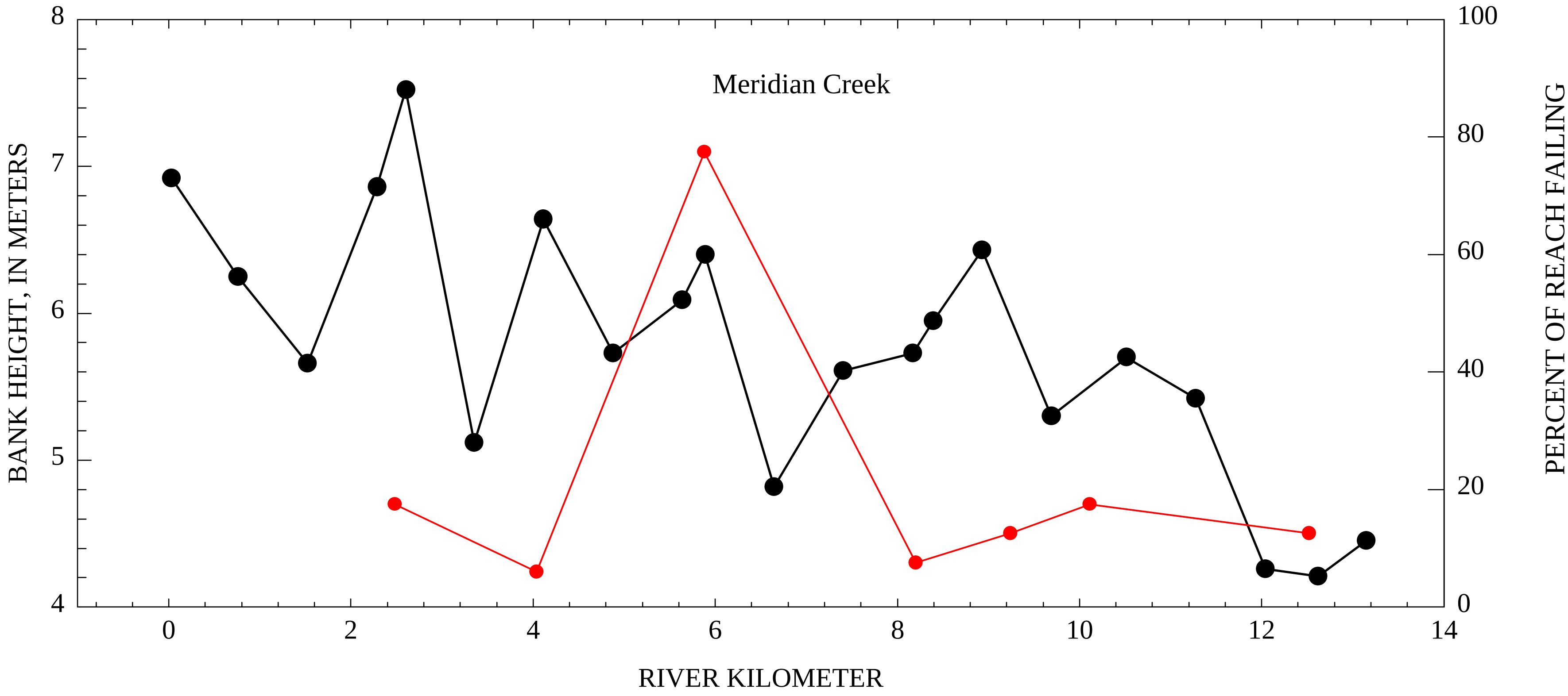


Figure 23K--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

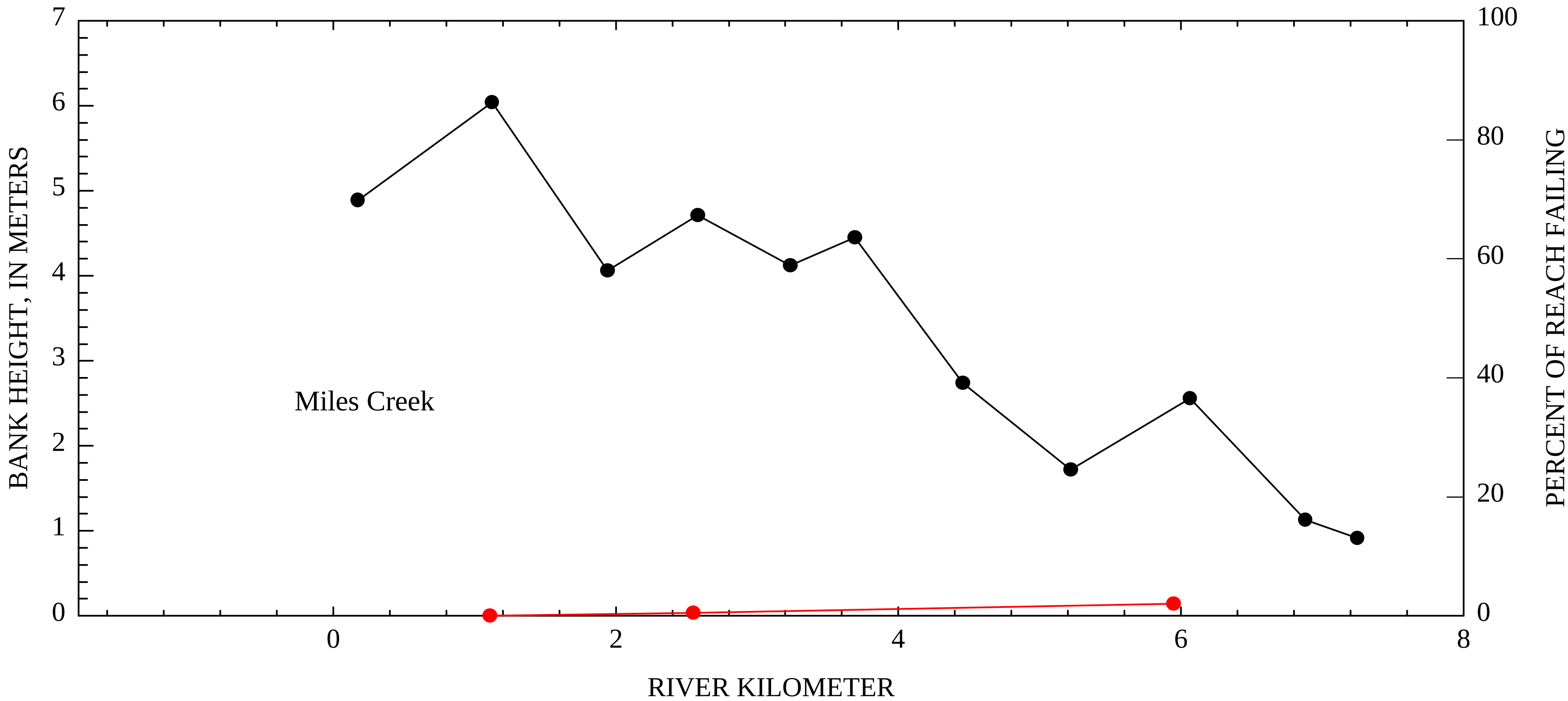


Figure 23L--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

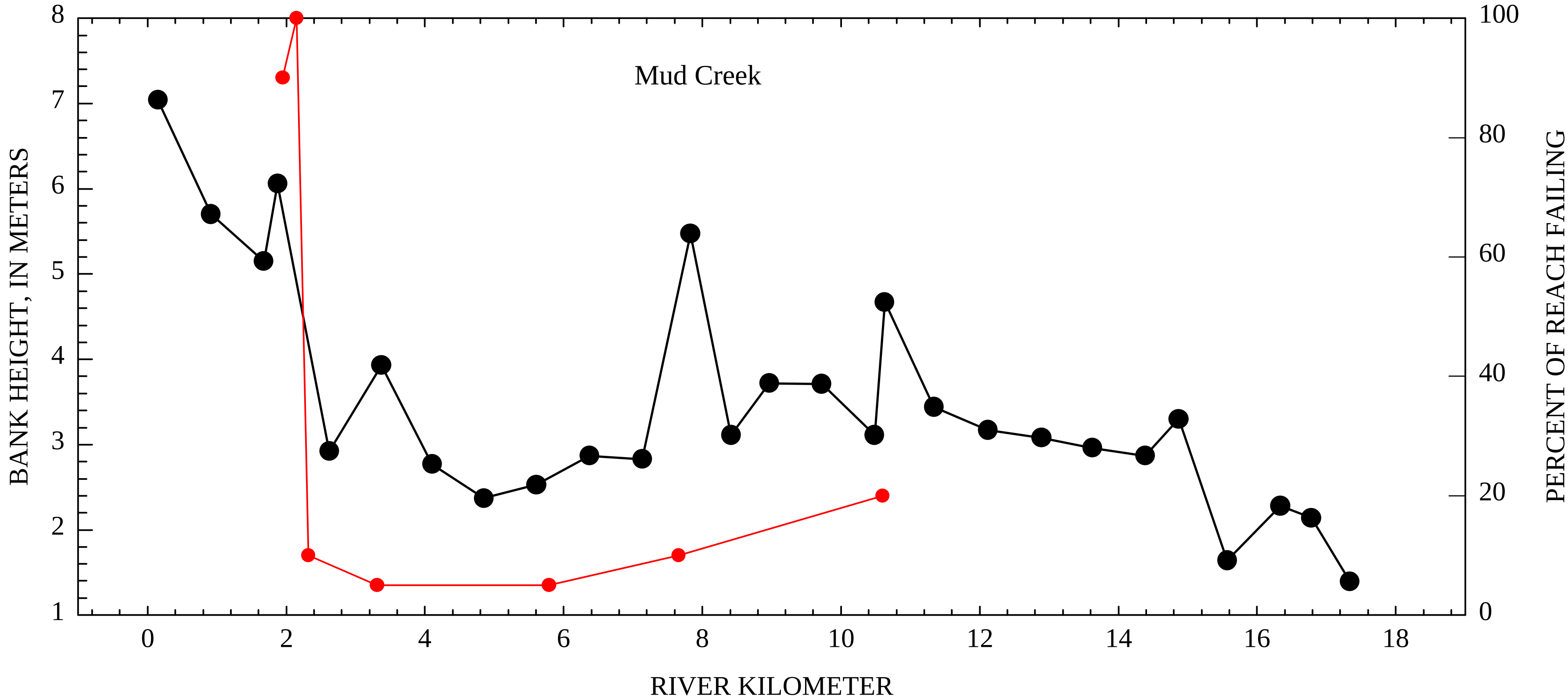


Figure 23M--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

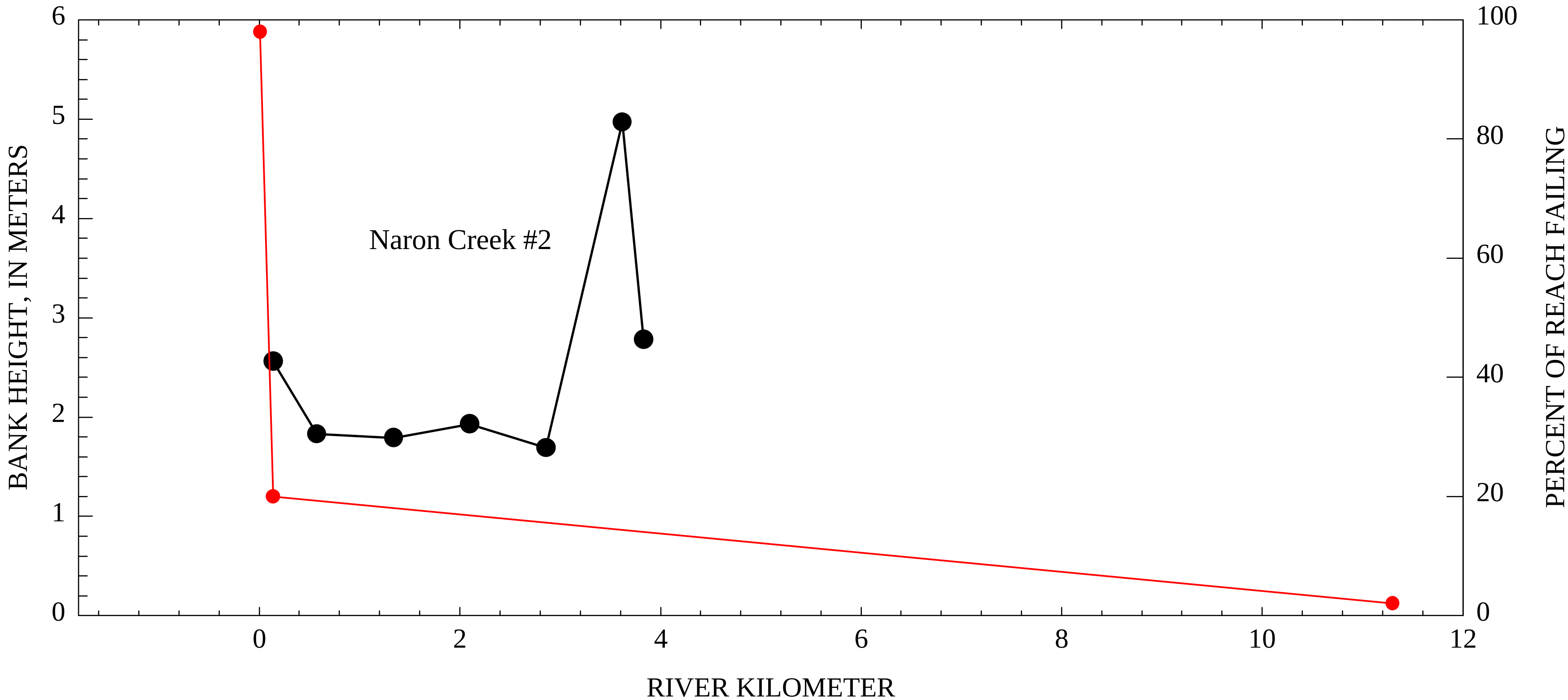


Figure 23N--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

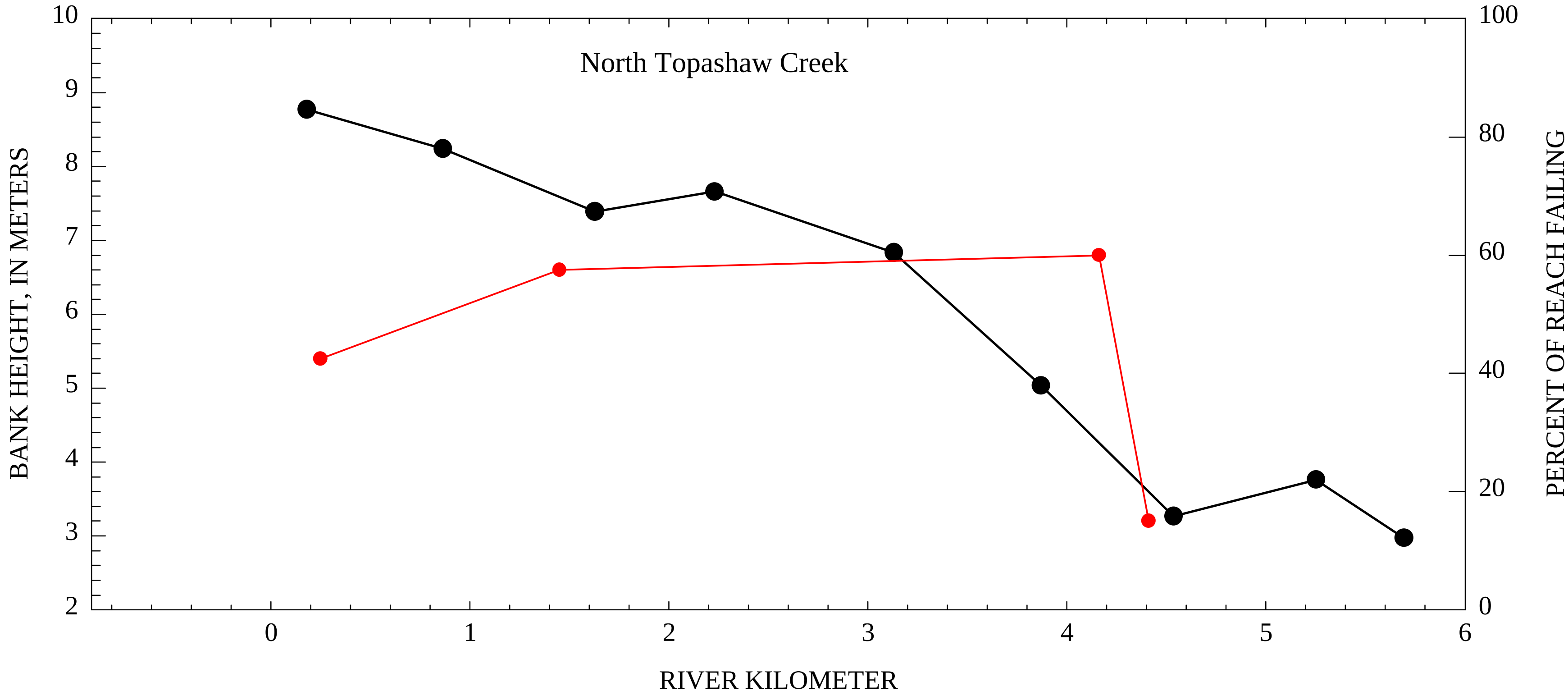


Figure 23O--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

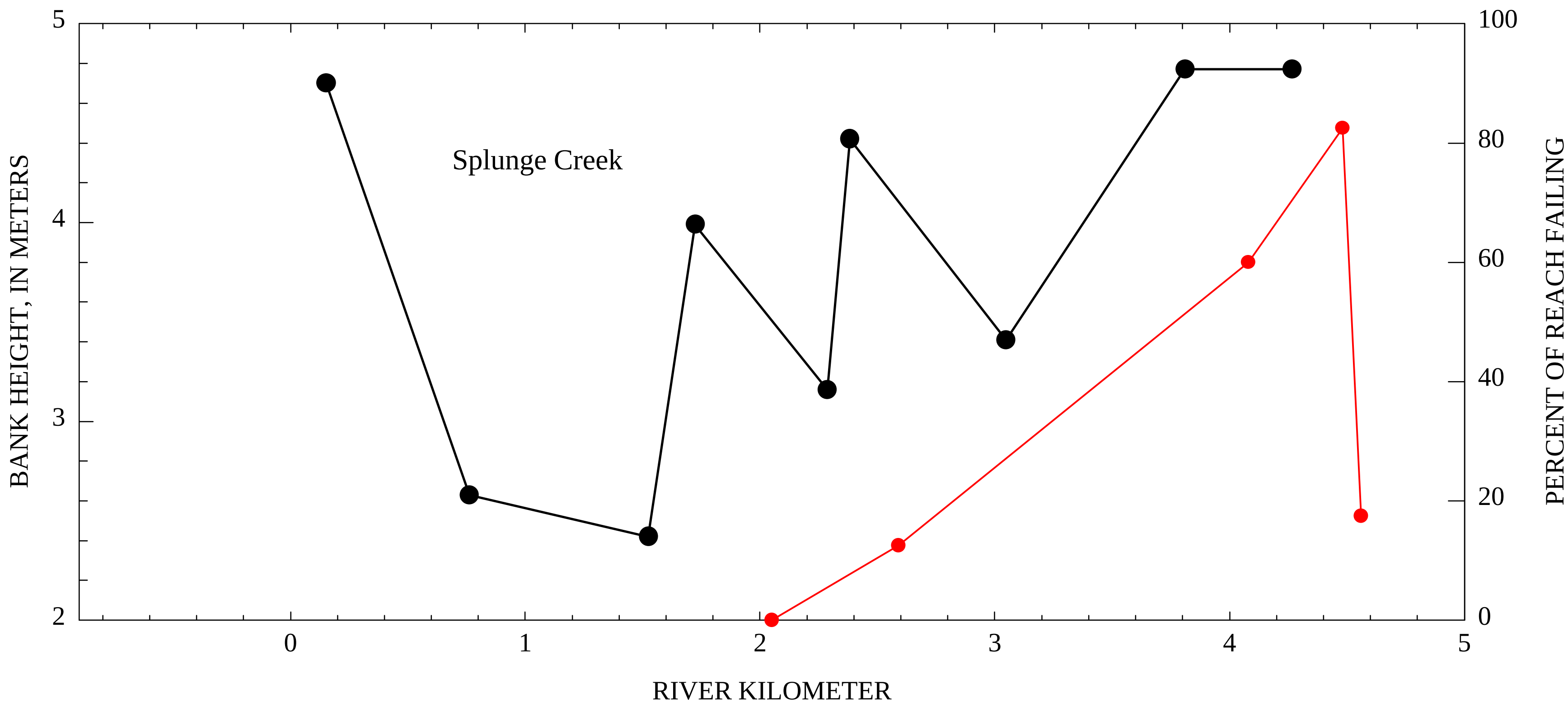


Figure 23P--Comparison of maximum bank heights with the percentage of the reach with failing banks for tributaries of the Yalobusha River System.

7. Little Topashaw Creek in the vicinity of and upstream of rkm 3
8. Mud Creek in the vicinity of and upstream of rkm 2
9. North Topashaw Creek in the vicinity of and upstream of rkm 4
10. Topashaw Creek in the vicinity of and upstream of rkm 21
11. Yalobusha River in the vicinity of and upstream of rkm 28

Stage III Conditions--Knickpoints and Knickzones

Upstream of the failing stage IV reaches are locations where the bed is degrading but bank heights and angles have not exceeded the critical conditions of the material and the banks remain stable and vegetated. Knickpoints and knickzones are cut into clays, including the Porters Creek Clay Formation and generally occur in the transition zones between stages V, IV, and III. They have also been observed in ironstone outcrops. For the purpose of this report, knickpoints and knickzones have been documented in two different ways: (1) by field inspection during the spring of 1997 (Table 8), and (2) by analysis of channel surveys obtained during the spring and summer of 1997 (Table 9). Although there are individual knickpoints in the order of 1.5 m high, knickzones with up to 3.5 m of drop over relatively short distances have been measured. Those streams with observed knickzones having more than a 1.5 m drop include Bear, Big, Buck, Bull, Miles, and Naron Creeks, Topashaw Tributary 1, North Topashaw Tributary 1, Yalobusha River.

A series of knickpoints on Big Creek between river kilometers 6.5 and 10.7 make this reach one of the most unstable in the basin. Other particularly unstable tributary reaches are the downstream ends of Dry, Johnson and Mud Creeks, and the middle reaches of Bear, Buck, Little and North Topashaw Creeks. The transition areas can be seen on Plate 2, in the series of graphs showing stage of channel evolution versus river kilometer (Appendix 1), and in the bank height (channel depth) versus river kilometer graphs (Figures 16-20).

Only where flows directly impinge on bank surfaces, such as on the outside of mildly sinuous or meandering reaches, are gravity-induced bank failures evident. These reaches may be characterized by steep bank surfaces smoothed by fluvial erosion and by trees with exposed root systems. Pore-pressure induced bank failures (termed “sapping” or “pop-out failures”) may, however, be observed. On the Yalobusha River, the transition to stage III conditions occurs downstream from the county-road bridge at Pyland (about river kilometer 30). On Topashaw Creek the transition to stage III also occurs at about river kilometer 30. Note that upstream of the stage III reaches on the Yalobusha River and numerous tributaries, stage I (premodified/ natural) or recovering stages V or VI occur. These conditions represent previous adjustment cycles that have moved through the river system. A good example of the migration of the current instability in the Yalobusha River System into these previously stabilized reaches can be found along the middle reaches of Bear Creek where stage V conditions have been overrun by a new wave of bed erosion and channel widening. Cut banks at the toe of previously stabilized bank surfaces, which supported mature woody vegetation, provide evidence of this recent re-incision.

Table 8--Location, size, and material type of major knickpoints in the Yalobusha River System as observed during 1997 field and aerial inspections.

Stream	Sub-basin	Basin	Site	River kilometer	Basin River kilometer	Number of Knickpoints	Total Height of Knickpoints (m)	Material
Topashaw T 1	Topashaw T 1	Topashaw	TT1-A	2.07	21.32	4	3.7	Clay
Bear	Bear	Topashaw	B2A	3.50	20.90	4	1.9	Clay
Buck	Buck	Topashaw	BU1-A	1.31	21.51	5	1.85	Clay
N. Topashaw T 1	N. Topashaw	Topashaw	NTT1-A	0.92	30.43	1	1.6	Box Culvert
Topashaw T 3	Topashaw T 3	Topashaw	TT3-A	0.12	31.12	1	1.45	Box Culvert
N. Topashaw	N. Topashaw	Topashaw	NT1-B	4.16	31.67	3	1.4	Clay
Topashaw T 1	Topashaw T 1	Topashaw	TT1-B	3.49	22.74	2	1.3	Clay
N. Topashaw T 2	N. Topashaw	Topashaw	NTT2-A	1.29	31.04	1	0.7	Clay
L.Topashaw	L Topashaw	Topashaw	LT1A	3.15	27.83	1	0.65	Clay
Bear	Bear	Topashaw	B3B	6.25	23.65	2	0.5	Clay
Bear	Bear	Topashaw	B3C	8.50	25.90	1	0.5	Clay
Buck	Buck	Topashaw	BU3-A	5.01	25.21	1	0.5	Clay
Topashaw	Topashaw	Topashaw	T7-A	27.10	31.14	1	0.5	Box Culvert
L.Topashaw T-2	L. Topashaw	Topashaw	LTT2-A	0.29	34.02	3	0.4	Clay
N. Topashaw	N. Topashaw	Topashaw	NT1-A	1.45	28.96	1	0.4	Clay
Topashaw	Topashaw	Topashaw	T2-C	9.97	14.01	1	0.4	Clay
Topashaw	Topashaw	Topashaw	T4	17.60	21.64	1	0.4	Clay
L.Topashaw T1	L Topashaw	Topashaw	LTT1-A	0.63	28.75	1	0.35	Clay
Bear	Bear	Topashaw	B1A	0.86	18.26	1	0.3	Clay
Dry	Dry	Topashaw	DRY3	5.01	31.07	1	0.3	Clay
N. Topashaw	N. Topashaw	Topashaw	NT1-C	4.41	31.92	1	0.3	Clay
L.Topashaw T-2	L. Topashaw	Topashaw	LTT2-B	1.39	35.12	1	0.25	Clay
L.Topashaw	L Topashaw	Topashaw	LT2-A	4.50	29.18	1	0.2	Clay
Buck	Buck	Topashaw	BU2-A	3.14	23.34	1	0.15	Clay
Buck	Buck	Topashaw	BU2-B	4.14	24.34	1	-	Clay
Bull	Bull	Yalobusha	Bull 1	1.1	26.80	1	2.1	Box Culvert
Miles	Miles	Yalobusha	M2-A	2.55	16.08	1	2.1	Rip, Rap
Big	Big	Yalobusha	Big5-B1	6.50	11.00	5	1.8	Clay
Naron	Johnson	Yalobusha	NM-A	0.01	25.26	3	1.6	Clay
Big	Big	Yalobusha	Big5-C	6.83	11.33	1	1.4	Clay
Yalobusha	Yalobusha	Yalobusha	Y3-E	28.80	28.80	1	1.4	Clay
Fair	Fair	Yalobusha	F2-A	8.01	41.65	1	1.2	Box Culvert
Mud	Mud	Yalobusha	MU1-B	2.15	29.36	1	1.2	Clay
Big	Big	Yalobusha	Big7-A	10.77	15.27	2	0.9	Clay
Johnson	Johnson	Yalobusha	JM-A	0.15	28.87	1	0.8	Clay
Johnson T 1	Johnson	Yalobusha	JT1-A	1.80	33.01	1	0.8	Box Culvert
Meridian T 1	Meridian	Yalobusha	MerT1-M-C	12.11	43.21	1	0.8	Clay
Cane(Cook)	Cane (Cook)	Yalobusha	C2-C	10.70	33.41	4	0.7	Clay
Splunge	Splunge	Yalobusha	S2-C	4.48	12.07	1	0.7	Clay
Yalobusha T 2	Yalobusha	Yalobusha	YT2-B	4.36	34.61	1	0.6	Clay
Big	Big	Yalobusha	Big7-B	15.69	20.19	2	0.5	Clay
Cane(Cook)	Cane (Cook)	Yalobusha	C3-B	11.27	33.98	2	0.5	Clay
Yalobusha	Yalobusha	Yalobusha	Y3-A	25.70	25.70	1	0.5	Clay
Walnut	Cane (Cook)	Yalobusha	WM-A	0.07	33.52	1	0.45	Clay
Bull	Bull	Yalobusha	Bull2	1.9	27.60	1	0.4	Clay
Bull	Bull	Yalobusha	Bull2-A	2.04	27.74	1	0.4	Clay
Bull	Bull	Yalobusha	Bull2-B	2.36	28.06	2	0.4	Clay
Cane (Cook)	Cane (Cook)	Yalobusha	C3-A	10.99	33.70	1	0.4	Clay
Splunge	Splunge	Yalobusha	S2-D	4.56	12.15	1	0.4	Clay
Cane(Cook)	Cane (Cook)	Yalobusha	C0-A	1.91	24.62	1	0.35	Clay
Meridian T 1	Meridian	Yalobusha	MerT1-M-B	11.22	42.32	1	0.3	Clay
Big	Big	Yalobusha	Big6-A	8.38	12.88	1	0.3	Clay
Cane (Cook)	Cane (Cook)	Yalobusha	C3-B	11.27	33.98	2	0.5	Clay
Johnson	Johnson	Yalobusha	JM-B	0.68	29.05	1	0.3	Clay
Johnson	Johnson	Yalobusha	J1-B	4.18	32.93	1	0.3	Clay
Splunge	Splunge	Yalobusha	S2-B	4.08	11.67	1	0.3	Clay
Walnut	Cane (Cook)	Yalobusha	W2-A	16.29	36.41	1	0.3	Clay
Yalobusha	Yalobusha	Yalobusha	Y5-A	34.80	34.80	1	0.3	Clay
Johnson	Johnson	Yalobusha	J1-A	1.21	29.96	2	0.25	Clay
Meridian	Meridian	Yalobusha	Mer3-A	5.88	26.87	1	0.25	Clay
Meridian	Meridian	Yalobusha	MerM-A	2.48	23.47	1	0.15	Clay
Miles	Miles	Yalobusha	M1-A	1.11	14.64	1	0.15	Clay
Walnut	Cane (Cook)	Yalobusha	W1-A	2.59	36.04	1	-	Clay

Table 9--Largest knick points in the Yalobusha River System as determined from 1997 surveys.

Corps of Engineers Stream Name	Agricultural Research Service Stream Name	Distance From Mouth (km)	Basin River Kilometer	Knick Point Height (m)
Anderson	**Anderson**	0.10	24.51	1.07
		0.02	24.43	1.00
		2.57	26.98	0.73
BC1 (Bull Trib)	**Bull T-1**	0.30	26.89	0.79
		0.05	26.64	0.67
		0.27	26.86	0.55
Big	**Big Creek**	6.77	11.17	2.13
		9.59	13.99	1.99
		6.50	10.90	1.49
Bull	**Bull**	1.14	26.84	2.21
		2.74	28.44	0.68
		2.02	27.72	0.21
Cane	**Cane**	12.00	34.71	0.76
		11.16	33.87	0.73
		13.78	36.49	0.27
Creek 1	**Huffman T-1**	1.84	21.54	0.73
Dry (Reach 2)	**Dry (Yalobusha)**	0.67	26.30	0.77
		0.50	26.13	0.61
		4.03	29.66	0.46
Duncan	**Duncan**	5.29	21.69	1.19
		9.28	25.68	0.70
		5.32	21.72	0.64
Gordon	**Gordon**	1.58	30.89	0.73
		5.30	34.61	0.39
		1.51	30.82	0.34
Huffman	**Huffman**	6.21	21.21	1.52
Hurricane	**Hurricane**	1.89	12.57	1.67
		5.65	16.33	1.40
		10.55	21.23	1.31
Hurricane 2	**Hurricane (Walnut Sub-baisin)**	0.37	32.75	1.34
		1.38	33.76	0.27
		3.55	35.93	0.52
Johnson	**Johnson**	0.22	28.94	0.97
		1.13	29.85	0.52
		0.86	29.58	0.38

Corps Of Engineers Stream Name	Agricultural Research Service Stream Name	Dist. From Mouth (km)	Basin River Kilometer	Knick Point Height (m)
M1	**Meridian T-2**	0.08	32.73	0.67
		0.62	33.27	0.61
		0.53	33.18	0.55

		0.38	33.03	0.33
M2	**Meridian T-1**	2.02	33.12	0.64
MC1	**Mud T-1**	1.42	30.51	0.91
MC2	-	0.52	-	0.70
MC4	**Mud T-3**	0.62	41.01	0.44
		0.85	41.24	0.33
		0.98	41.37	0.28
		0.87	41.26	0.27
Miles	**Miles**	6.55	20.08	1.24
Mud	**Mud**	2.16	29.37	1.47
		15.53	42.74	0.64
		15.97	43.18	0.43
		1.65	28.86	0.37
Naron 1	-	0.24		4.80
Naron 2	**Naron (Trib. Of Johnson)**	1.04	26.29	0.84
Naron Trib T-1	-	0.46	-	0.70
Twin	**Twin**	1.23	23.26	0.57
		1.52	23.55	0.57
Yalobusha River	**Yalobusha**	30.14	30.14	2.49
		29.15	29.15	1.40
		28.39	28.39	0.84
		25.82	25.82	0.67
W1	**Walnut T-1**	0.79	38.82	1.35
		0.57	38.60	0.83
		0.30	38.33	0.67
Walnut	**Walnut**	2.26	35.71	0.96
Yalobusha River Trib YR-1	**Yalobusha T-2**	3.08	33.33	0.56
Yalobusha River Trib YR-2	**Yalobusha T-1**	3.52	15.40	0.45

Indicates a knick point not observed during 1997 field reconnaissance.

Area-Gradient Index and Historical Thalweg Elevations

The area-gradient-index (AGI), defined as the product of channel gradient and drainage area, can be used as a surrogate for total stream power and provides an indication of a stream's sediment-transporting capacity. When plotted against river kilometer, locations of maximum instability can be identified as "peaks" in the AGI. This is shown in Figure 24 by coincident AGI peaks for Yalobusha River and Topashaw and Bear Creeks in the vicinity of basin river kilometers 24-28. That the peaks are coincident clearly identifies the erosional response in the Yalobusha River System as being systematic in nature, and operating along the two primary channels in a similar fashion.

The apparent AGI-peaks at basin river kilometers 10-16 for both major streams do not represent current erosional reaches of large sediment-transporting capacity but locations just upstream of the "lake-like" effects of the sediment/debris plug which are characterized by very low AGI values (Figures 24 and 25). Reaches between river kilometers 10-16 are currently characterized as stage V (Plate 2). Still, these reaches have degraded more than other reaches and may represent the "area of maximum disturbance" in the system. Along both the Yalobusha and Topashaw main stems, the highest banks (about 14 m) occur here (Figures 16 and 17). These locally steep reaches may, in part, be the result of outcrops of clay at the upper end of the reach. The extremely low AGI values for the lower Yalobusha River main stem are easily identified by comparing values from 1967 and 1997 (Figure 25A). 1997-values downstream of basin river kilometer 10.0 are representative of these backwater conditions and provide further justification for disregarding the five downstream-most points in the stage VI stable-gradient relation (equation 2).

Empirical Bed-level Model for the Yalobusha River

Historical thalweg data were used to identify temporal changes in bed elevation at the locations shown in Figure 26. A dimensionless exponential equation (Simon, 1992), was used to fit these data to represernt bed-level change at-a-site with time. Examples of fitting the historical data to the equation is shown in Figure 27 for an aggradational setting (cross section Y-1) and for a degradational setting (cross section Y-13).

$$z / z_0 = a + b\, e^{(-k\, t)} \qquad (3)$$

where z = elevation of the channel bed (at time t);

z_o = elevation of the channel bed at t_o;

a = dimensionless coefficient, determined by regression and equal to the dimensionless elevation (z/z_o) when equation (3) becomes asymptotic, a>1 = aggradation, a<1 = degradation;

b = the dimensionless coefficient, determined by regression and equal to the total change in the dimensionless elevation (z/z_o) when equation (3) becomes asymptotic;

k = the coefficient determined by regression, indicative of the rate of change on the channel bed per unit time; and

t = the time since the year prior to the onset of the adjustment process, in years (t_o=0).

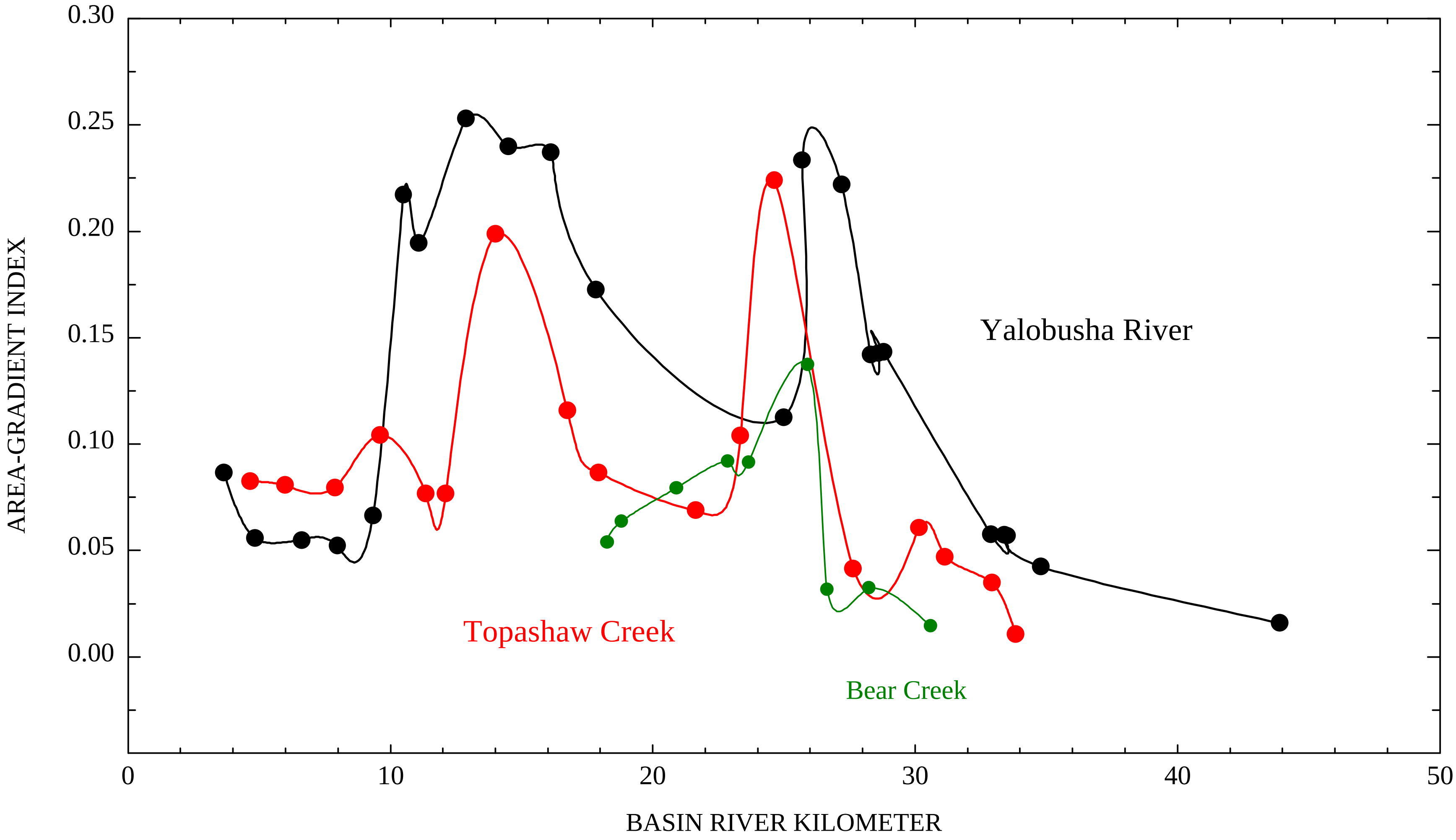


Figure 24--Area-gradient-index values for Yalobusha River, Topashaw Creek and Bear Creek, showing peak values between basin river-kilometers 24-28.

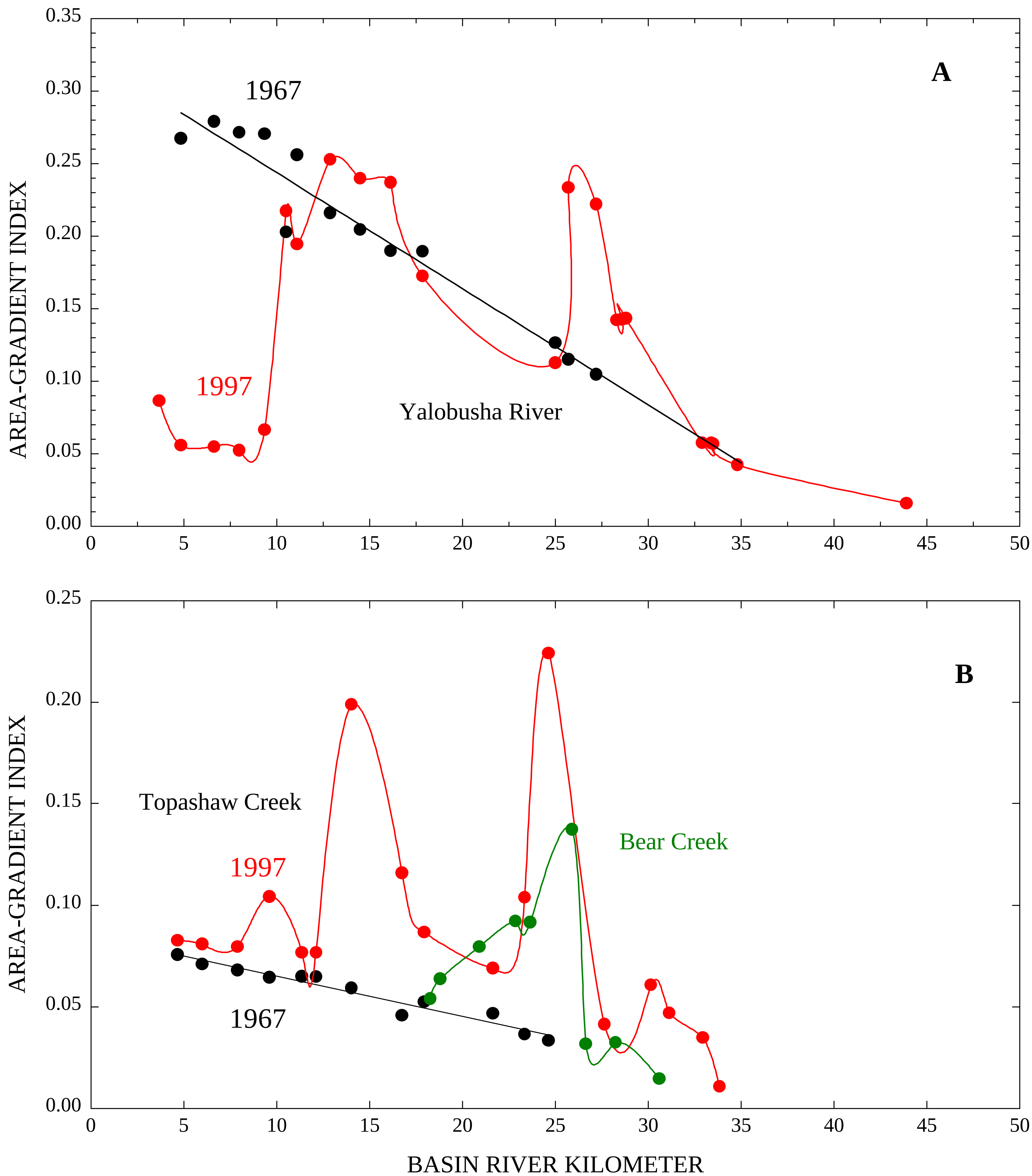


Figure 25--Comparison of area-gradient-index (AGI) values for 1967 and 1997 along the Yalobusha River main stem. Note the extremely low values below river kilometer 10 due to prolonged backwater conditions (A), and AGI values for Topashaw and Bear Creeks showing synchronous peaks at river kilometers 24-28 and Topashaw AGI peak at river kilometer 15 (B).

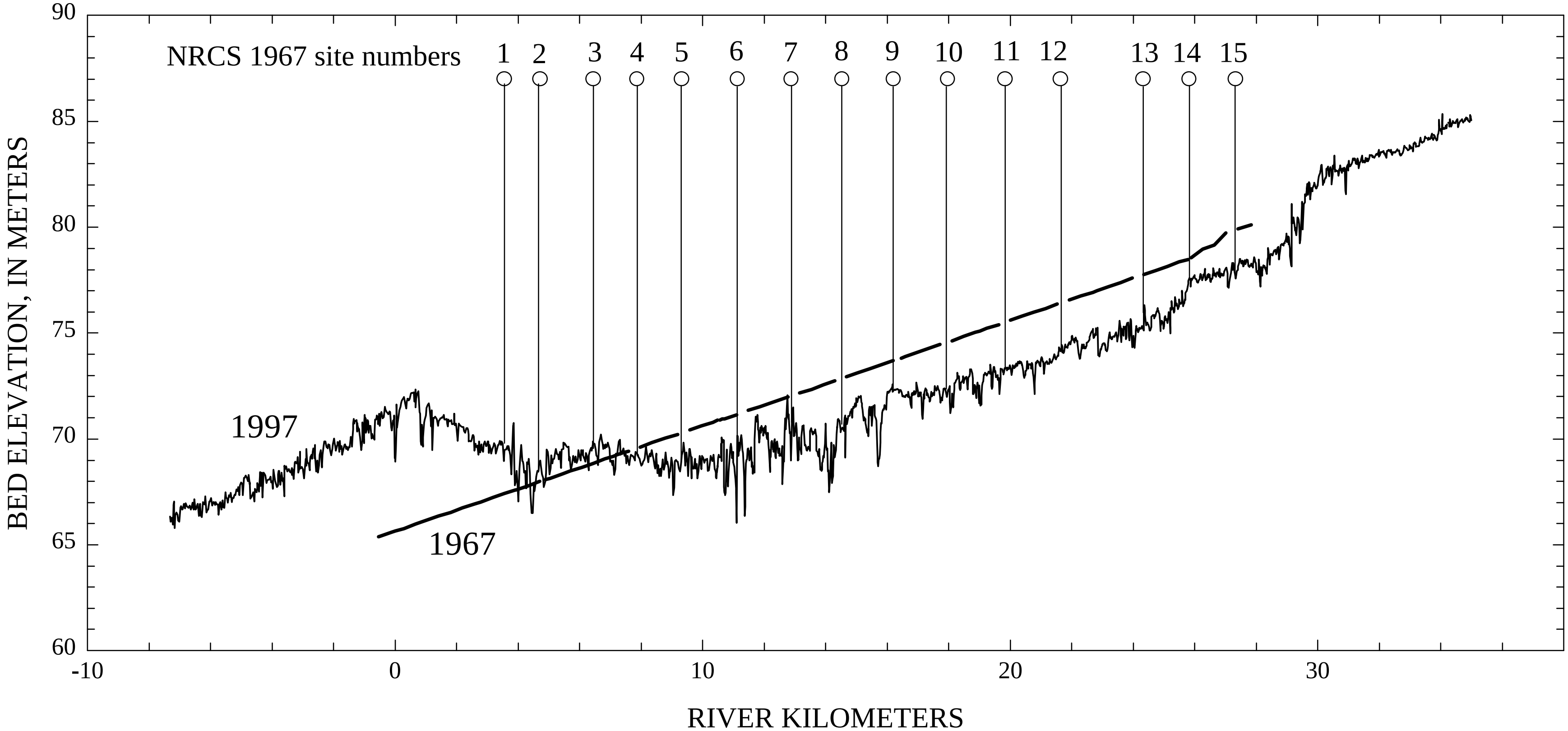


Figure 26--Yalobusha River profiles from 1967 and 1997 showing NRCS cross-section locations.

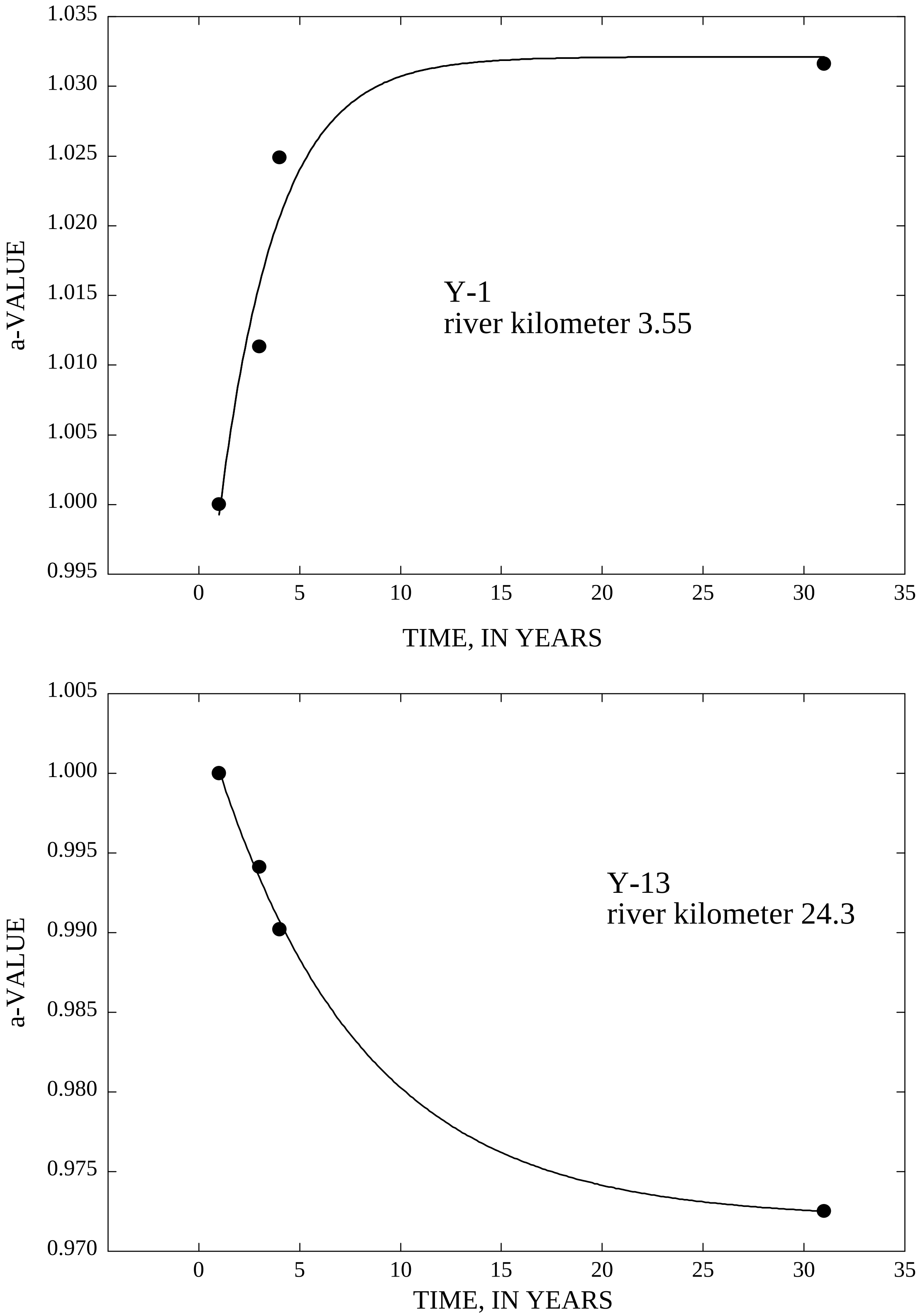


Figure 27--Examples of fitting historical bed-elevation data to equation 3.

The a-value is a convenient parameter to identify long-term changes in bed elevation because it represents the elevation (z / z_o) in the future. An a-value of 1.0 signifies that the long-term elevation will be equal to the initial elevation. The lower the value, the greater the amount of degradation. Results (*a*-values) are plotted against distance upstream to develop an empirical model of bed-level response (Figure 28): Minimum *a*-values for the Yalobusha River main stem occur in the vicinity of river kilometer 15, with a secondary minimum between river kilometers 22 and 25. These locations coincide with the local peaks in AGI shown in Figures 24 and 25. Future dimensionless elevations of the channel bed can be estimated by substituting the coefficients listed in Table 10 and different time values into equation 3 for the time period of interest. These values can then be converted to bed elevation by multiplying a site's *a*-value by the initial bed elevation (z_o).

BED MATERIAL CHARACTERISTICS

In the transition areas between stage V and stage IV, the dominant type of bed material changes gradually from fine or medium sand, to firm clay and is often accompanied by knickpoints or knickzones. The sand is relatively uniform with an average d_{50} of about 0.35 mm (0.27 – 0.39 mm on the lower Yalobusha; 0.24 – 0.48 mm on the lower Topashaw).

In some cases the clay is the Porters Creek Clay Formation of the Midway Group. This hard, dark gray to black clay has undrained cohesive strengths as great as 287 kPa (Mississippi Department of Transportation, written commun.). Notwithstanding the strength of the clay formation, the Yalobusha River, Topashaw Creek, and other degrading tributary streams in the basin have been able to incise as much as 1.5 m into this resistant material. Generally, sand-sized bed material dominates in downstream stage V and VI reaches and clay beds dominate in upstream stage IV and III reaches (Plates 1 and 2). The presence of clay on channel beds in degrading reaches indicates a general lack of hydraulically-controlled bed material. This further indicates that sediment-transport rates are probably considerably less than capacity for most if not all flows. Strategies for stable slopes and hydraulic conditions must account for this imbalance between available flow energy and the limited sediment availability from the channel bed.

It is the presence of the resistant clay material that makes the Yalobusha River System somewhat unique in comparison to other adjusting stream systems in the mid-continent region. A geologic section taken longitudinally along the Yalobusha River shows the Midway Group as the dominant formation in the valley (Newcome and Bettandorff, 1973; Plate 1). The clays are found on the channel beds as:

1. relatively smooth and solid ledges (much like bedrock),
2. rounded sand-, to gravel-, to cobble-sized clasts, or
3. desiccated flakes in the clay-size range.

Prediction of critical shear stress criteria and rates of channel-bed erosion under various mitigation scenarios must, therefore, be adaptable to Shields-type analysis for the rounded, flocculated clasts of fine-grained material, but also as a truly cohesive bed material. Clearly, the shear stress required to erode these cohesive materials will vary throughout the year as the characteristics of the cohesive materials change.

Table 10—Regression data used to develop empirical model of bed-level response for historic cross sections on the Yalobusha River main stem (See Figure 28). Note a, b, and k are regression coefficients; r^2 = coefficient of determination.

Cross section	**River kilometer**	**Initial (1967) elevation z_o (m)**	a	b	k	r^2
Y-1	3.55	67.36	1.0321	-.0321	-	.934
Y-2	4.72	67.82	-	-	-	-
Y-3	6.45	68.88	-	-	-	-
Y-4	7.86	69.49	.9962	.0051	.2862	1.00
Y-5	9.31	70.26	-	-	-	-
Y-6	11.1	71.17	-	-	-	-
Y-7	12.9	72.09	.9702	.0322	.1059	.964
Y-8	14.5	72.85	.9572	.0453	.0671	.996
Y-9	16.2	73.69	.9480	.0557	.8377	.991
Y-10	18.0	74.60	.9696	.0460	.4159	1.00
Y-11	19.8	75.51	.9744	.0320	.2333	.990
Y-12	21.6	76.43	.9700	.0356	.1849	.992
Y-13	24.3	77.72	.9720	.0323	.1365	.998
Y-14	25.8	78.71	.9863	.0182	.2962	.993
Y-15	27.3	79.25	.9819	.0201	.0911	.993

Incipient Motion of Bed Material

To address the problem of estimating critical-shear stresses and stable channel gradients, erosion tests on representative clay beds in the Yalobusha River System were conducted during the spring, 1998 with a submersible jet device (Hanson, 1991).Sites on Big, Bear, Buck, Cane, and Topashaw Creeks were tested. Preliminary results indicate that the critical shear stress required to entrain these materials ranged over an order of magnitude; from 32 to 393 Pa (mean = 158 Pa; standard error = 32.3 Pa). Using the average boundary shear stress as:

$$\tau_o = \gamma \; y \, S \qquad (4)$$

where τ_o = boundary shear stress in N/m^2; γ = unit weight of water, in N/m^3; y = flow depth, in meters; and S = channel gradient, in m/m, and the Shields criteria, we can calculate an equivalent particle diameter for the measured critical shear stresses:

$$\tau_* = \tau_o / (\gamma_s - \gamma) \, d \qquad (5)$$

where τ_* = critical dimensionless shear stress; γ_s = unit weight of sediment in N/m^3;; and d = a representative particle diameter, in meters.

Using a bed slope of 0.001 m/m and a flow depth of 8m (approximately bankfull in the transition reach of the Yalobusha River), by equation (4), boundary shear stress becomes about 78 Pa. This shear stress is generally not sufficient to erode the *in-situ* clay beds, a steeper gradient being required. However, using the measured critical shear stress of 158 Pa, and by substituting this value into equation (5) and assuming $\tau_* = 0.03$ and $(\gamma_s - \gamma)$ = 1,650 kg/m^3 * 9.81 m/s^{-2}, results in an equivalent diameter d, of about 33 cm. Erosion of the clay beds is, therefore, equivalent to entraining particles with diameters of about 0.3 m. In contrast, only 0.17 Pa is required to entrain the 0.35mm sand, characteristic of the downstream ends of the Yalobusha River and Topashaw Creek. The ease that channel degradation has proceeded through the sand-bedded portions of the watershed is indicated by the low shear stress required to erode the sand beds. By using equation (4), it is shown that at a channel gradient of 0.001, 0.17 Pa is attained at a flow depth of just less than 2 cm. Erosion of the 0.35mm sand from reaches just upstream of the sediment/debris plug would require a flow depth of only 4.3 cm assuming the current average channel gradient of 0.0004 m/m. Clearly, these flow depths are exceeded the majority of the time.

That migration of some knickpoints or erosion zones has been severely limited is directly related to the resistance of these clay beds. More than 30 years after the completion of the most recent channel dredging on the Yalobusha River main stem, the major erosion zone is still just upstream of the upstream terminus of the channel work (river kilometer 27.8).

It is as if the Yalobusha River system has cut through the available sandy alluvium on the channel beds, leaving only the resistant clays of the Midway Group (including the Porters Creek Clay Formation). This hypothesis is supported by the episodic nature of aggradation recorded at the downstream gaging stations (Figure 15). Although episodic behavior can be due solely to rejuvenation of tributary beds, in the Yalobusha River System there is little alluvium

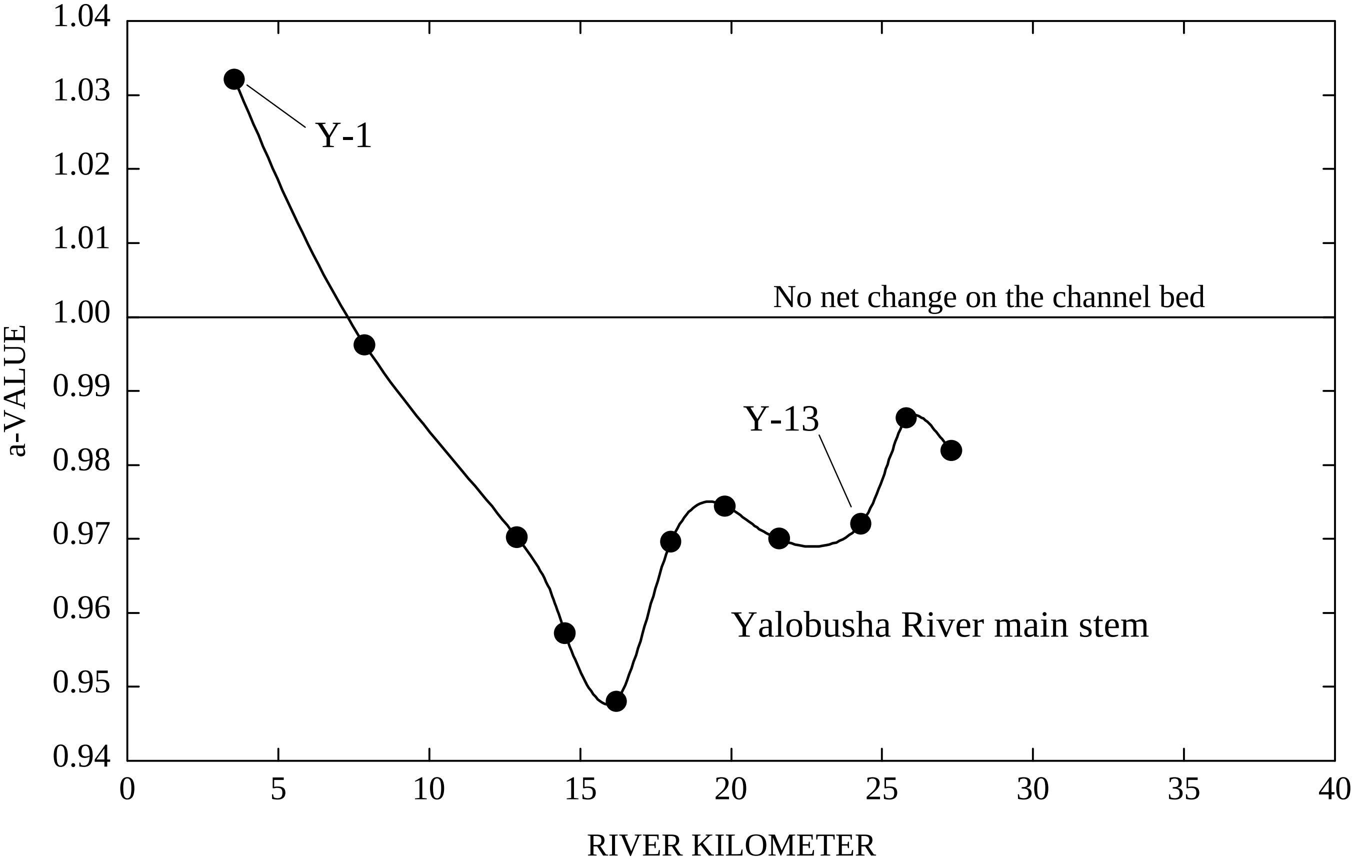


Figure 28-- Empirical model of bed-level response for the Yalobusha River main stem derived from historical bed-elevation data fit to equation 3. Note location of example cross sections Y-1 and Y-13.

on tributary beds to supply downstream reaches and cause episodic aggradation. It is more likely then that these episodes of downstream aggradation are associated with periods of accelerated bank erosion during years when the banks have remained saturated for long periods. This does not necessarily require the greatest peak flows, but rather, a great frequency of peak flows such as 1979, 1983, and 1991. Dendrochronologic data from streambanks throughout the Yalobusha River System point to these dates as periods of accelerated channel widening.

SEDIMENT BUDGETS AND YIELDS

Adjustment of the Yalobusha River System is somewhat different than other disturbed system because of the resistant nature of its clay beds. In unstable channel systems, which have excess stream power and energy relative to bed-material load, the system tends to reduce stream power and energy by adjusting aspects of its morphology, hydraulics, and sediment load. Generally, this takes place by increasing bed-material loads through erosion of sand- or gravel-sized materials from the channel bed in upstream reaches, with consequent deposition in downstream reaches. If there is an insufficient supply of sediment from the channel bed, however, the channel system maintains excess power and obtains the discrepancy between transporting capacity and sediment availability from the channel banks (Simon and Darby, 1997). This seems to be the case with the Yalobusha River System and was tested by analyzing the relative contributions of bed and bank material over the past 31 years.

Sediment budgets for selected streams of the Yalobusha River Basin were calculated by comparing 1967 as-built construction plans provided by the NRCS with 1997 channel-survey data provided by the U.S. Army Corps of Engineers. Sufficient data were available to determine budgets for the Yalobusha River and Topashaw Creek main stems, and Bear, Big, Cane, Hurricane, Miles, and Splunge Creeks.

To calculate a sediment budget for each stream, bank heights, channel top widths, channel bottom widths and thalweg elevations were obtained for 1967 and 1997. The 1967 and 1997 values of a given parameter were plotted against river kilometer on the same graph and compared. This method provided rapid assessment of general amounts of widening, narrowing, deepening, and filling along each of the streams. Volumes eroded/deposited along the channel bed were determined by calculating the area between the 1967 and 1997 thalweg profiles and multiplying this value by the average bottom width over the period. To provide a more detailed analysis, stream lengths were broken down into shorter reaches to account for changes in bottom width over time and distance. Similarly, the area enclosed by overlain plots of 1967 and 1997 channel top widths was multiplied by the average bank height over the period to obtain the volume of bank material eroded/deposited along the channel boundary. Volumes of sediment eroded/deposited are reported in cubic meters per year per meter of stream channel.

Results from all 8 streams show that the channel banks contribute at least 85% and as much as 92% of the sediment eroded from the channels of the Yalobusha River System (Table 11). The reason values are higher than those previously reported in the literature and are directly related to the lack of sediment available on the channel bed. To determine sediment yield in metric tons per square kilometer of drainage area, channel volumes were multiplied by an assumed density of 2,000 kilograms per cubic meter. Sediment yields range from about 320

Table 11--Sediment budgets for selected streams of the Yalobusha River System.

		Volume Eroded (+) Volume Deposited (-)									
	Reach	Stream Bed	Erosion per Length of Channel	Stream Banks	Erosion per Length of Channel	Average Erosion of Stream Bed	Proportion Erosion of Stream Bank	Proportion Eroded From Banks (Using Total Volume)	Proportion Eroded From Banks (Using Effected Length)	Sediment Discharge[1]	Sediment Yield
	km	m^3	m^3/m	m^3	m^3/m	m/yr	m/yr	%	%	tons/yr	$tons/km^2/yr$
Bear Creek	0 - 3	66,100	22.0	342,000	114.0	0.132	0.601	-	-	26,300	-
	3 - 6	51,700	17.2	367,000	122.0	0.111	0.723	-	-	27,000	-
	6 - 9	28,100	9.37	139,000	46.3	0.0730	0.361	-	-	10,800	-
49.0 km^2	**Total**	146,000	16.2	848,000	94.2	0.1053	0.562	85.3%	85.3%	64,100	1,310
Big Creek	0 - 2.2	-18,000	-8.20	40,200	18.3	-0.0467	0.0305	-	-	1,427	-
	2.2 - 6.8	37,900	8.24	193,000	41.9	0.0466	0.0699	-	-	14,900	-
	6.8 - 9.7	28,200	9.72	194,000	67.0	0.0659	0.125	-	-	14,400	-
42.9 km^2	**Total**	48,000	6.41	427,000	44.0	0.0219	0.075	89.9%	87.3%	30,700	710
Cane Creek	0 - 3.4	61,100	18.0	418,000	123.0	0.0748	0.730	-	-	30,900	-
	3.4 - 7.2	66,800	18.6	499,000	139.0	0.0920	0.865	-	-	36,500	-
	7.2 - 13	79,200	13.2	641,000	107.0	0.0719	0.798	-	-	46,400	-
64.4 km^2	**Total**	207,000	15.7	1,558,000	118.0	0.0796	0.798	88.3%	88.3%	114,000	1,770
Hurricane Creek	0 - 2	7,290	3.64	186,000	93.1	0.0239	0.714	-	-	12,490	-
	2 - 4	11,400	5.71	136,000	68.2	0.0372	0.476	-	-	9,530	-
	4 - 6	21,500	10.75	157,000	78.5	0.0619	0.654	-	-	11,500	-
	6 - 9	31,000	10.34	120,000	39.9	0.0664	0.357	-	-	9,720	-
	9 - 12	8,450	2.82	90,300	30.1	0.0311	0.246	-	-	6,370	-
48.6 km^2	**Total**	79,700	6.64	690,000	57.5	0.0441	0.489	89.6%	89.6%	49,600	1,020
Miles Creek	0 - 2	9,740	4.87	156,000	78.0	0.0352	0.678	-	-	10,700	-
	2 - 4.5	14,000	5.60	111,000	44.4	0.0415	0.464	-	-	8,060	-
15.7 km^2	**Total**	23,700	5.28	267,000	59.3	0.0384	0.571	91.8%	91.8%	18,800	1,190
Splunge Creek	0 - 1	-6,790	-6.79	9,880	9.88	0.0399	0.0928	-	-	199	-
	1 - 2	0.00	0.00	25,900	25.9	0.000	0.347	-	-	1,670	-
	2 - 4.9	8,270	2.85	69,000	23.8	0.0292	0.241	-	-	4,990	-
19.4 km^2	**Total**	8,270	2.12	105,000	21.4	0.0230	0.227	92.7%	91.0%	7,300	380
Toposhaw Creek	0 - 3.17	-53,000	-16.6	352,000	111.0	-0.0290	0.631	-	-	19,300	-
	3.2 - 5.9	13,400	0.00	477,000	174.0	0.000	0.875	-	-	31,700	-
	5.9 - 7.2	12,400	9.37	222,000	169.0	0.0198	0.798	-	-	15,200	-
	7.2 - 10	43,300	15.7	428,000	155.0	0.0365	0.699	-	-	30,400	-
	10 - 15	121,000	24.1	1,596,000	319.0	0.0687	1.349	-	-	110,800	-
	15 - 20	89,300	17.9	758,000	152.0	0.0718	0.620	-	-	54,700	-
276 km^2	**Total**	279,000	16.6	3,835,000	192.0	0.0280	0.829	93.2%	92.0%	265,000	960
Yalobusha River	0 - 5.1	-	-	-603,000	116.0	-	-0.759	-	-	-38,900	-
	0 - 8.2	-507,000	-61.6	-	-	-0.0659	-	-	-	-32,700	-
	5.1 - 10	-	-	478,000	99.2	-	0.501	-	-	30,800	-
	8.2 - 10	61,000	34.5	-	-	0.0421	-	-	-	3,940	-
	10 - 20	468,000	46.8	2,008,000	201.0	0.0684	0.842	-	-	159,700	-
	20 - 30	293,000	29.3	2,066,000	207.0	0.0648	1.025	-	-	152,200	-
887 km^2	**Total**	315,000	14.5	4,073,000	164.0	0.0584	0.402	90.0%	90.0%	283,000	320

[1] - Assumed Density of eroded material is 2000 kg/m^3

t/km^2/yr for the Yalobusha River main stem to almost 1,800 t/km^2/yr for Cane Creek (Table 11).

SHEAR STRENGTH AND CHANNEL-BANK STABILITY

The resistance of a channel bank to mass failure is a function of the shear strength of the bank material. Shear strength comprises two components-- cohesive strength and frictional strength. For the simple case of a planar failure of unit length the Coulomb equation is applicable:

$$S_r = c' + (s - m) \tan f' \tag{6}$$

where S_r= shear stress at failure,
c' = effective cohesion,
s = normal stress on the failure plane,
m = pore pressure, and
f' = effective friction angle.

Also,

$$s = W (\cos \beta) \tag{7}$$

where W = weight of the failure block, and
β = angle of the failure plane.

The gravitational force acting on the bank is $W \sin. \beta$ Factors that decrease the erosional resistance (S_r) such as excess pore pressure from saturation and the development of vertical tension cracks favor bank instabilities. Similarly, increases in bank height by bed degradation and bank angle by undercutting favor bank failure by causing the gravitational component to increase. In contrast, vegetated banks are generally drier and provide improved bank drainage, which enhances bank stability (Thorne, 1990). However, recent work by Collison and Anderson (1996) suggests that the effects of roots, at least in the humid tropics may reduce shearing resistance because of enhanced permeability and hence, greater delivery of water to the subsurface. Plant roots provide tensile strength to the soil which is generally strong in compression, resulting in reinforced earth (Vidal, 1969) that resists mass failure, at least to the depth of vegetation roots. However, the added weight of woody vegetation on a bank acts as a surcharge and can have negative effects on bank stability by increasing the downslope component of weight, particularly on steep banks. Matric suction, caused by negative pore pressures that exist above the water table also increases the shearing resistance of the bank in the unsaturated zone and helps to determine accurate values of effective cohesion, shear strength, and stable-bank geometries (Fredlund, et al., 1978; Curini, 1997; Simon and Curini, 1998).

Shear Strength Testing

Data on cohesion and friction angle were obtained from *in-situ* shear-strength testing with a borehole shear tester (BST). The instrument provides drained, effective parameter values for use in stability analyses. Testing was undertaken in 21 sites throughout the Yalobusha River System (38 tests) to depths of about 6.8 m. Additional deep testing was to be undertaken but could not due to unforeseen circumstances with NSL drilling equipment. To substitute for the lack of deeper BST testing, triaxial-test data were obtained for several sites in the watershed from the

Table 12--Summary of geotechnical data collected in the Yalobusha River System.

Stream	Site	Date	Depth (meters)	Soil Type	c' (kPa)	ϕ' (degrees)	Type of Test	$\rho_{ambient}$ (g/cm^3)	ρ_{dry} (g/cm^3)	$\gamma_{ambient}$ (kN/m^3)	γ_{dry} (kN/m^3)	Moisture Content
Bear	B-3	4/29/97	1.40	ML	7.00	38.70	BST	1.47	1.32	14.4	13.0	11%
Bear	B-3	4/29/97	2.20	ML	-	-	BST	1.61	1.44	15.7	14.2	11%
Bear	B-4	4/3/97	1.00	MH/CL	6.73	22.80	BST	1.54	1.23	15.1	12.1	25%
Bear	B-4	4/3/97	1.50	CL	4.60	24.20	BST	1.83	1.45	18.0	14.3	26%
Big	Big-2	4/21/97	1.00	SM	3.00	31.80	BST	1.55	1.36	15.3	13.4	14%
Big	Big-7	7/2/97	1.77	MH	1.05	29.90	BST	1.81	1.41	17.7	13.8	28%
Big	Big-7	12/23/97	3.04	OL	10.00	6.00	BST	1.86	1.60	18.2	15.8	16%
Cane	C-2	3/31/97	0.80	MH	1.00	38.00	BST	1.53	1.38	15.0	13.6	11%
Cane	C-2	4/2/97	1.10	MH	0.75	38.70	BST	-	-	-	-	-
Cane	C-2	4/2/97	1.70	MH	2.29	36.10	BST	1.62	1.39	15.9	13.7	17%
Duncan	D-2	4/10/97	0.90	MH	12.90	27.50	BST	1.91	1.61	18.8	15.8	19%
Duncan	D-2	4/10/97	1.30	MH	4.60	25.20	BST	1.61	1.39	15.8	13.6	16%
Little Topashaw	LT-1	5/14/97	1.00	SM	7.00	32.60	BST	-	-	-	-	-
Meridian	Mer-1	4/23/97	1.10	ML	2.50	36.90	BST	1.62	1.33	15.9	13.1	22%
Meridian	Mer-1	4/23/97	1.80	ML	8.80	25.60	BST	1.84	1.55	18.1	15.2	19%
Meridian	Mer-4	4/21/97	1.00	MH	7.00	30.90	BST	1.93	1.70	18.9	16.6	14%
Mud	Mud-5	4/8/97	1.00	CL	6.32	23.30	BST	1.76	1.37	17.3	13.4	29%
Mud	Mud-5	4/9/97	1.50	CL	5.80	19.80	BST	1.78	1.38	17.5	13.5	30%
Topashaw	T-1	3/26/97	2.70	CL	0.08	19.30	BST	1.72	1.26	16.8	12.4	36%
Topashaw	T-2B	4/24/97	2.00	CL	11.50	21.30	BST	1.84	1.49	18.1	14.6	24%
Topashaw	T-2B	4/24/97	2.50	CL-CH	24.20	18.90	BST	1.93	1.59	19.0	15.6	22%
Topashaw	T-3	3/24/97	1.20	CL	7.92	21.30	BST	1.78	1.39	17.4	13.6	28%
Topashaw	T-3	3/24/97	2.80	CL	16.40	21.80	BST	1.75	1.42	17.1	13.9	23%
Topashaw	T-4	4/25/97	1.60	CH	20.50	17.20	BST	1.75	1.38	17.2	13.6	26%
Topashaw	T-4	12/31/97	4.32	OH	6.12	29.00	BST	1.96	1.70	19.2	16.7	15%
Topashaw	T-4	12/31/97	6.75	OH	7.20	21.88	BST	1.77	1.45	17.4	14.3	22%
Topashaw	T-5	3/11/97	1.00	CL	8.83	16.20	BST	1.61	1.34	15.9	13.1	26%
Topashaw	T-5	3/11/97	2.00	CL	6.67	30.50	BST	1.77	1.44	17.4	14.2	23%
Topashaw	T-7	12/22/97	4.26	OL	2.50	17.00	BST	1.74	1.39	17.1	13.7	24%
Topashaw	T-8	3/10/97	1.00	CL	5.54	29.70	BST	1.91	1.48	18.8	14.5	29%
Topashaw	T-8	3/10/97	1.10	CL	17.90	16.70	BST	1.76	1.35	17.3	13.2	31%
Walnut	W-2	4/9/97	0.90	CL-MH	1.40	34.20	BST	1.64	1.32	16.1	12.9	24%
Yalobusha	Y-1	3/21/97	1.20	CL	1.12	32.00	BST	1.58	1.26	15.6	12.3	25%
Yalobusha	Y2	2/28/97	1.50	CL	2.83	27.20	BST	-	-	-	-	-
Yalobusha	Y-2	3/18/97	2.00	CL	3.80	23.30	BST	1.72	1.30	16.9	12.7	32%
Yalobusha	Y2	2/26/97	2.20	CL	3.47	24.50	BST	-	-	-	-	-
Yalobusha	Y-3	3/17/97	1.00	CL	8.55	31.40	BST	1.62	1.28	15.9	12.6	27%
Yalobusha	Y-3	3/17/97	2.00	CL	13.90	18.30	BST	1.69	1.31	16.6	12.9	29%
HurricaneTrib	@Hur-2	10/2/92	2.44	CL	10.53	6.00	TRI*	-	1.19	-	15.7	21%
HurricaneTrib	@Hur-2	10/2/92	4.27	SM	23.92	26.00	TRI*	-	1.23	-	16.2	21%
Hurricane	Hur-2	10/2/92	0.92	CL	10.53	6.00	TRI*	-	1.14	-	15.0	26%
Hurricane	Hur-2	10/2/92	2.14	SM	23.92	26.00	TRI*	-	1.26	-	16.7	20%
Hurricane	Hur-2	10/2/92	2.60	SP	0.00	34.00	TRI*	-	1.10	-	14.5	28%
Yalobousha	Y-3	8/1/83	5.19	CL	33.49	12.00	TRI*	-	1.12	-	14.8	26%

Legend:

* Data from Mississippi Department of Transportation

Test Types:
BST - Borehole Shear Test
TRI - Triaxial Shear Test

Variables:
c' = Effective cohesion
ϕ' = Effective friction angle
$\rho_{ambient}$ = ambient density
ρ_{dry} = dry density
$\gamma_{ambient}$ = ambient unit weight
γ_{dry} = dry unit weight

Mississippi Department of Transportation (MDOT). Shear strength and unit weight data are provided in Table 12.

Bank-Stability Analysis

Data collected with the BST are used to represent the uppermost unit comprising the channel banks. These data were split into 2 groups, one representing tests conducted along the Yalobusha River and Topashaw Creek main stems, and the other representing tests conducted along tributary streams. Distributions of the shear-strength parameters *c'* and *f'* as well as the soil unit weight (γ) are clearly non-normal, justifying the use of median values as representative values (Figures 29 and 30). For the tributaries these values are: *c'* = 5.8 kPa, *f'* = 29.9^o, and γ = 16.6 kN/m^3; for the main stems: *c'* = 7.2 kPa, *f'* =21.8 ^{o}, and γ = 17.2 kN/m^3.

Stratigraphic information obtained from the 1967 construction plans indicates that below this upper unit, Yalobusha River tributary banks contain layers of low plasticity clay, and in some cases, a layer of silty sand. Tributary banks are, therefore, further subdivided into those with and without this sandy unit. Typical *c'* and *f'* values for the low plasticity clay units were obtained for the tributary streams from MDOT: 17.2 kPa and 16 ^{o}, respectively. For the sand units *c'* = 0.00 kPa, and *f'* = 35.0^o. Equal weightings were assigned to the shear-strength values of each unit. Shear-strength parameters values for the tributaries with the sand unit are: *c'* = 7.7 kPa, *f'* = 26.5^o, γ = 16.7 kN/m^3 (Cane, Duncan, Huffman, and Meridian Creeks) For tributaries without the sand unit, the parameter values are: *c'* = 11.5 kPa, *f'* = 22.3^o, γ = 16.9 kN/m^3 (Bear and the other Topashaw River tributaries, Hurricane, Miles and Splunge Creeks).

Stratigraphic information for the main-stem channels indicate 2 principle units that would be subjective to bank failures. The upper unit comprises about 90% of the bank height and is composed composed of sandy clays. The lower unit is composed of low-plasticity clays and, on average, comprises about 10% of the total bank height. Shear-strength values used to represent these banks are an average of the values obtained during BST testing (*c'* = 9.2 kPa, *f'* = 22.8^o, γ = 17.2 kN/m^3) and the deep values obtained from the MDOT for the low-plasticity clays (*c'* = 33.5 kPa, and *f'* = 12^o). These values were weighted according to their contribution to the total bank height, resulting in final shear-strength parameter values of: *c'* = 11.6 kPa, *f'* = 21.8^o, γ = 17.2 kN/m^3. None of the failures observed in the field cut through the Porters Creek Clay Formation. Shear-strength data for this formation were, therefore, not incorporated into the bank-stability analyses. A summary of geotechnical parameter values used is shown in Table13.

Table 13--Geotechnical parameter values used to develop bank-stability charts.

	c' (in kPa)	*f'* (in degrees)	γ (in kN/m^3)
Yalobusha River and Topashaw Creek	11.6	21.8	17.2
Tributaries without sand unit	11.5	22.3	16.9
Tributaries with sand unit	7.7	26.5	16.7

The most common type of bank failure along streams of the Yalobusha River System are wedge-shaped planar failures. These failures occur on steep slopes which have often been undercut by flow. The Culmann analysis is appropriate for steep slopes and is used to conduct

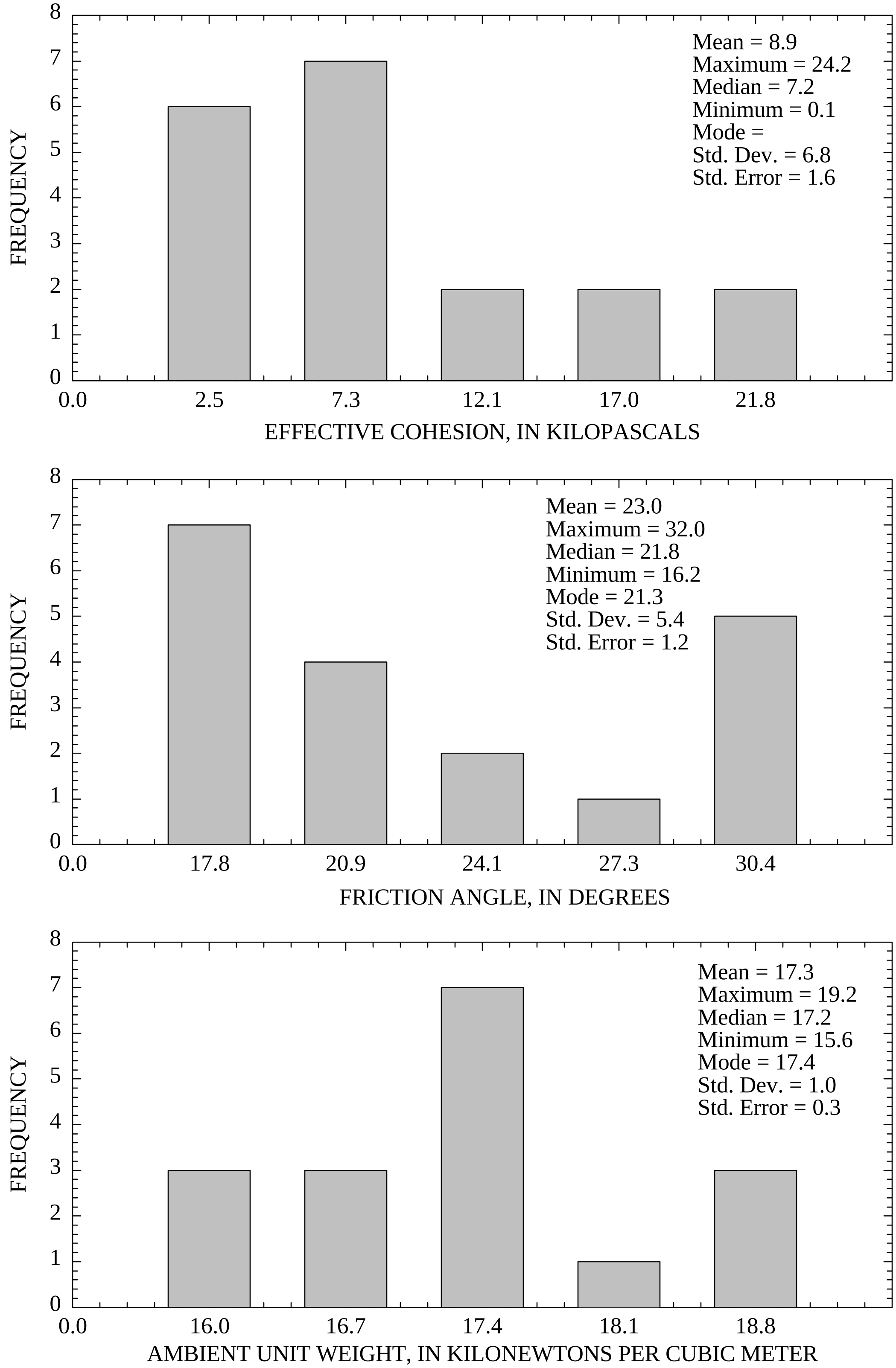


Figure 29--Frequency histograms of geotechnical data for sites along the Yalobusha River and Topashaw Creek.

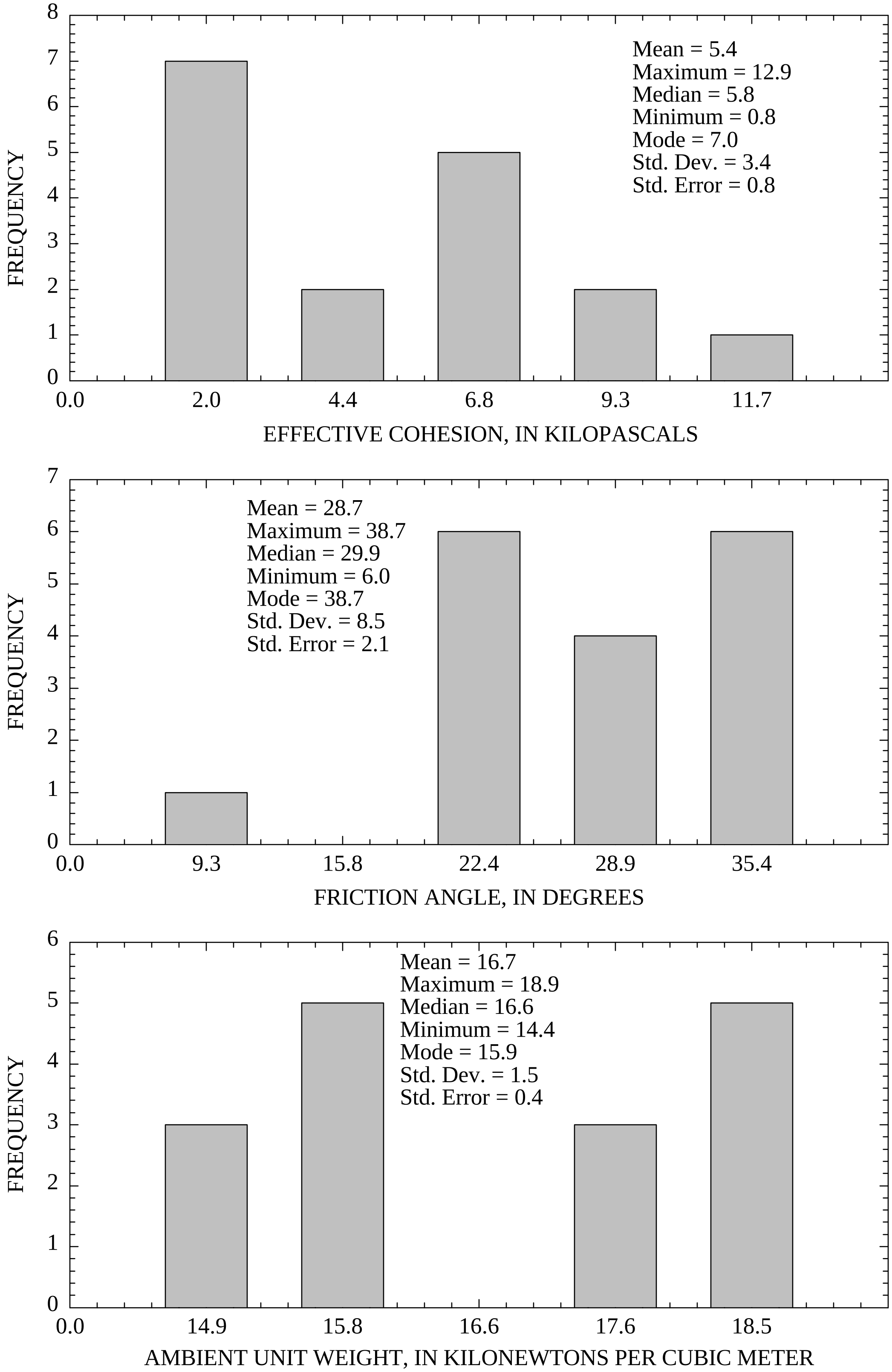


Figure 30--Frequency histograms of geotechnical data for sites along tributaries of the Yalobusha River System.

stability analyses for these types of failures. The bank will fail when a certain critical height is reached at a given bank angle. Critical bank height (H_c; above which there would be mass failure) is obtained from Culmann (1866):

$$H_c = (4c' / g) (sin a \cos f') / [1 - \cos (a - f')] \qquad (8)$$

where g = unit weight, and
α = bank angle.

The effects of tension cracks on H_c can estimated by subtracting the tension crack depth (z) from the critical bank height:

$$z = 2\, c_u / g \qquad (9)$$

where c_u = undrained cohesive strength.
If c_u data are not available, the depth of tension cracking can be estimated in the field from the height of the vertical face (Simon, 1989).

Iterating equation (8) for bank angles of 90, 80, 70, 60, 50 and 40^o, results in a bank-stability charts for ambient field conditions (Figure 31A-C). This procedure is then repeated assuming that the banks are undrained and that f = 0.0 (Lutton, 1974) to obtain H_c values under saturated (worst case) conditions, resulting in the lower line of the figures. The effect of "worst-case" conditions on decreasing H_c can be seen by drawing a vertical line anywhere on Figure 31 and comparing the difference in values at the intersection of the ambient- and undrained-condition lines. The critical bank conditions shown in Figure 31 do not directly account for the effects of pore-water pressures in the banks or the confining pressure afforded by the water in the channel. This latter factor becomes important in assessing bank stability in reaches of the Yalobusha River downstream from Calhoun City where the debris jam has caused deeper flows.

The frequency of bank failure for the three stability classes is subjective but is based on empirical field data from southeastern Nebraska, northern Mississippi, western Iowa, and West Tennessee. An "unstable" channel bank can be expected to fail at least annually and possibly after each major flow event (assuming that there is at least one in a given year). "At-risk" conditions indicate that bank failure can be expected every 2-5 years, again assuming that there is a runoff event that is sufficient to saturate the channel banks. "Stable" banks by definition do not fail by mass-wasting processes. Although channel banks on the outside of meander bends may widen by particle-by-particle erosion and may ultimately lead to collapse of the upper part of the bank, for the purposes of this discussion, stable-bank conditions refer to the absence of mass wasting.

During the majority of the year, when the banks are relatively dry, ambient conditions can be used to assess streambank stability. Thus a vertical bank 4 m-high would represent the maximum stable height for the main stem channels and for tributaries without sand in the banks. However, this height reduces to about 2.5 m when excess pore-water pressures are generated (Figure 31). A similar comparison of ambient and worst-case conditions for a 1:1 slope (45^o) results in values of about 23 and 7 m, respectively. For bank instability to be observed, the critical conditions only need to have been exceeded frequently enough in the recent past so as not to be hidden by other channel processes (such as fluvial deposition) in the reach. This may be annually as in the "unstable" case, or it may be every few years, as in the "at-risk" case. By combining field

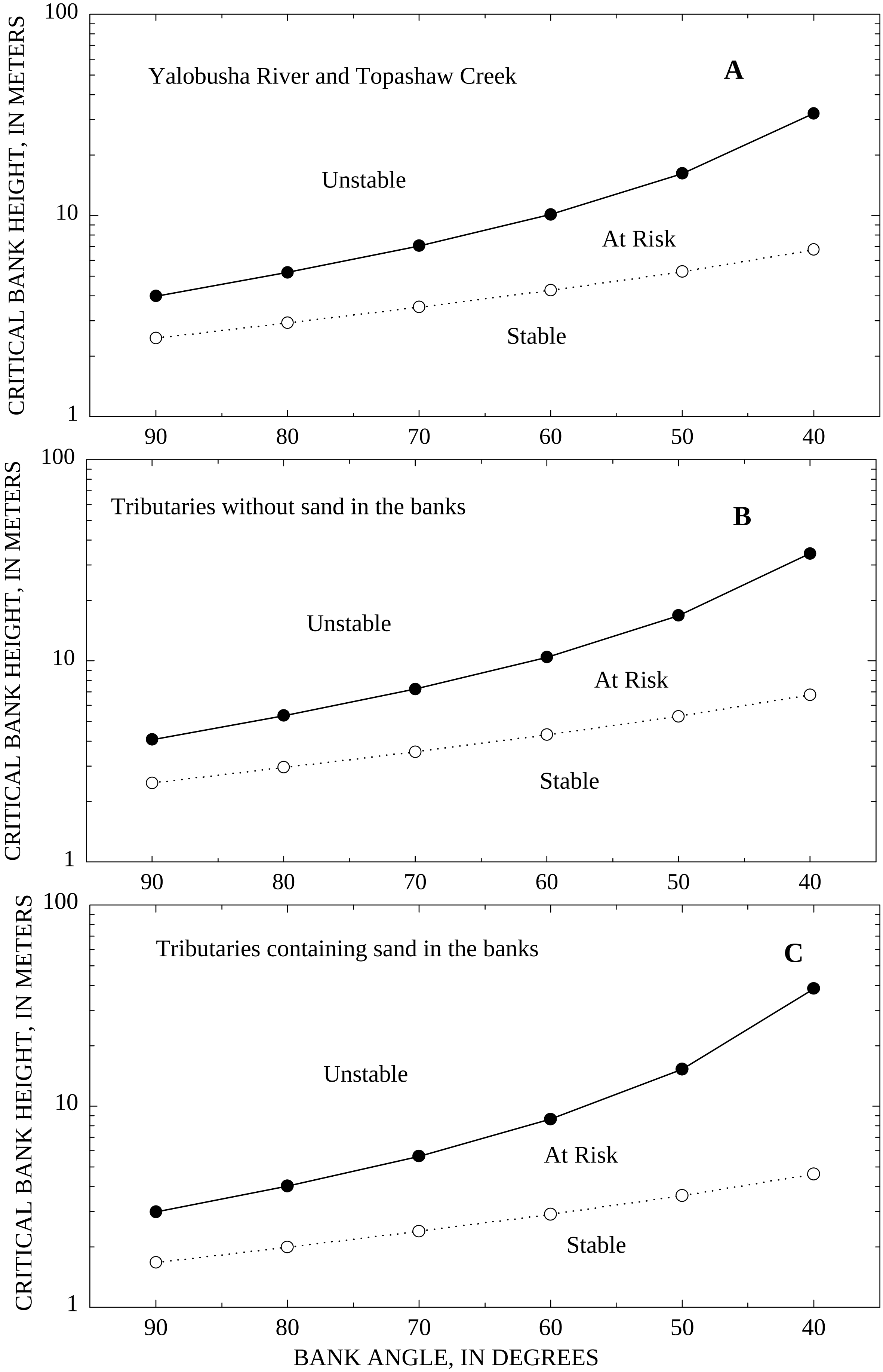


Figure 31--Bank-stability charts for streambanks of the Yalobusha River and Topashaw Creek (A); tributaries without a sand unit (B); and tributaries containing a sand unit (C).

evidence of bank failures, expressed as the percent of the reach (longitudinally) failing, with the maximum bank height in the reach, an informative picture of bank-stability conditions is obtained. Figures 21-23 show the relation between bank height and percent of reach failing for most of the streams in the Yalobusha River System. Peaks in the "percent-of-reach-failing" data indicate reaches of severe bank instability. In the most general terms and without consideration of confining pressures, bank heights in excess of about 5 m are unstable.

Factor of Safety Analysis for Current and Future Conditions

Consideration of pore-water and confining pressures were included in a more sophisticated analysis of bank stability to evaluate present and long-term stability conditions. Analyses of current and future bank-stability conditions were conducted using an equation for the factor of safety (F_s) which includes the effects of bank hydrology:

$$F_s = \frac{c' L + [\,(W \cos b) - U + P \cos(a - b)\,] \tan f'}{W \cdot \sin b - [P \sin(a - b)]} \tag{10}$$

Where L = length of the failure surface, in m,
U= hydrostatic uplift force acting on the failure surface, in kN/m,
P= hydrostatic confining force due to external water level, in kN/m, and
a = bank angle, in degrees

The critical conditions (bank failure) occurs at F_s = 1.0. Assuming a bank geometry as shown in Figure 32, the length of the failure surface (L) and the weight of the failure block (W) are obtained:

$$L = H / \sin b \tag{11}$$

$$W = 0.5 \cdot \gamma \cdot [\, H^2 / \cdot \tan b - H^2 / \cdot \tan a \,] \tag{12}$$

Where γ = soil unit weight and is assumed constant and independent from the degree of saturation in kN/m^3, and
H= bank height as measured from the flood-plain surface or levee top, to the proximal channel bed, in m.

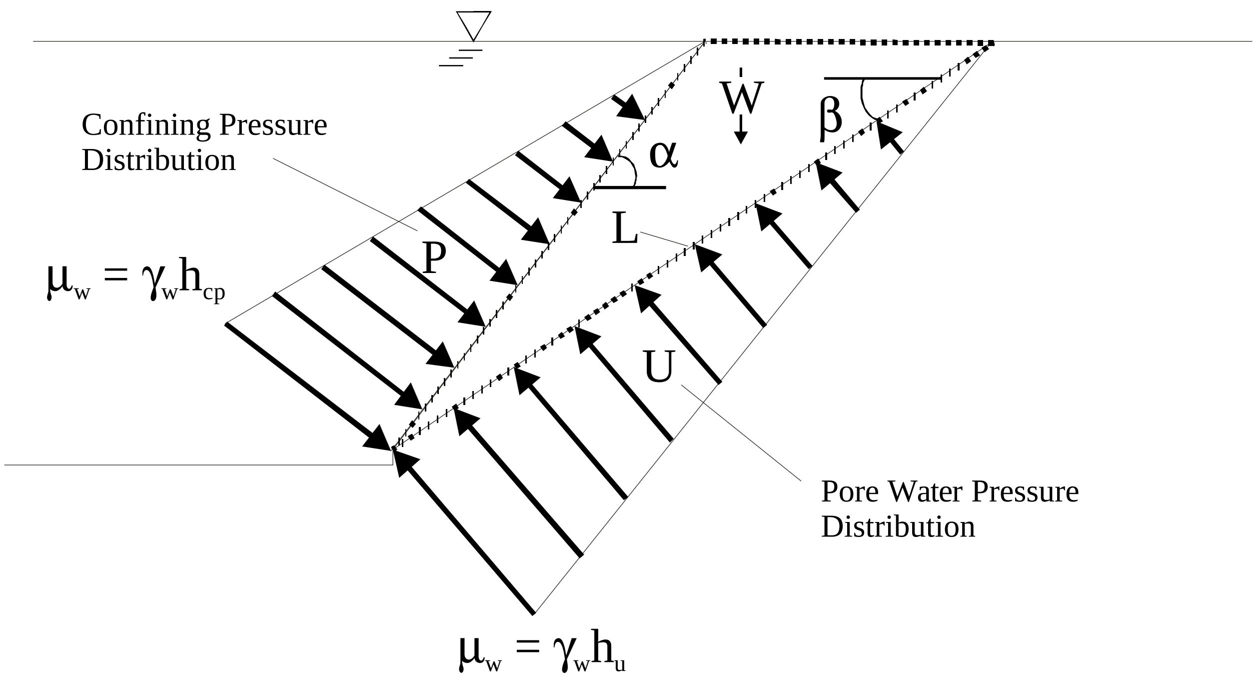


Figure 32 -- Bank geometry used for F_s analysis showing pertinent forces (see equations 10-15). Note: L = length of failure surface, in m; U = hydrostatic uplift force acting on the failure surface, in kN/m; P = hydrostatic confining force due to external water level, in kN/m; W = weight of the failure block, in kN/m; α = bank angle, in degrees; β = failure plane angle, in degrees; μ_w = water pressure at a point, in kN/m^2; γ_w = 9.81 kN/m^3; h_u = pore-water head, in m; h_{cp} = confining-water head, in m.

The uplift (*U*) and confining (*P*) forces are calculated from the area of the pressure distribution of pore-water ($h_u \cdot \gamma_w$) and confining ($h_{cp} \cdot \gamma_w$) pressures (μ_w) as shown in Figure 32.

$$U = 0.5\ \gamma_w\ h_u^2 / \sin b \tag{13}$$

$$P = 0.5\ \gamma_w\ h_{cp}^2 / \sin \alpha \tag{14}$$

Where γ_w = 9.81 kN/m^3,

h_u = pore-water head, in m and

h_{cp} = confining-water head, in m.

The failure plane angle is represented by (Carson, 1971):

$$b = 0.5\ (a + f\prime) \tag{15}$$

Current conditions along specific reaches are differentiated on the basis of the height of the (1) phreatic surface (or pore-water pressure; H_u) and (2) river stage (or confining pressure; H_{cp}), relative to the total bank height. These are expressed as percentages of the total bank height. Two reaches can be described for the Yalobusha River and Topashaw Creek based on low-water (ambient) conditions: a downstream reach where H_u and H_{cp} values are 50% owing to the long-term backwater conditions and a middle-upstream reach where H_u and H_{cp} values are 5% owing to the long-term degraded conditions. Except for the lower reaches of Bear Creek, the hydrologic conditions of the tributaries are represented by the conditions on the middle and lower reaches of the main-stem channels. Rapid drawdown (worst-case) conditions for downstream main-stem channels are represented by H_u = 95% and H_{cp} = 50%; for the middle and upper main-stem reaches, and for tributary streams H_u = 75% and H_{cp} = 5%.

Conditions Along Lower Yalobusha River and Topashaw Creek

Results for current conditions along the downstream ends of the main-stem channels are shown in Figures 33A-35A for bank heights of 4, 6, and 8 m. As can be seen from this series of figures, F_s decreases with increasing bank height for a given set of H_{cp} and H_u combinations (Tables 14-16). Similarly, as pore pressures increase, F_s decreases (Figures 33A-35A). At a bank height of 4 m, banks are unstable only at angles steeper than 75^o and when H_u = 95%. In reaches where bank heights are 8 m, all bank slopes are unstable at H_u = 95%, as are those steeper than about 55^o at H_u = 75%. A summary of current bank-stability conditions for these reaches can be obtained from the H_{cp} = 50% column of Tables 14-16.

Effects of Removal of Sediment/Debris Plug

Removal of the sediment/debris plug can effect bank stability along the lower Yalobusha River and Topashaw and Big Creeks. Plug removal was analyzed as a long-term case (H_u = 5% and H_{cp} = 5%), where the phreatic surface has time to adjust to the lowering of water levels and, as a short-term, rapid-drawdown case where the phreatic surface cannot adjust rapidly enough because of rapid draining of channel water. The rapid-drawdown case was modeled assuming that flow levels in the channel would drop significantly and thus H_{cp} = 5% with a corresponding H_u =

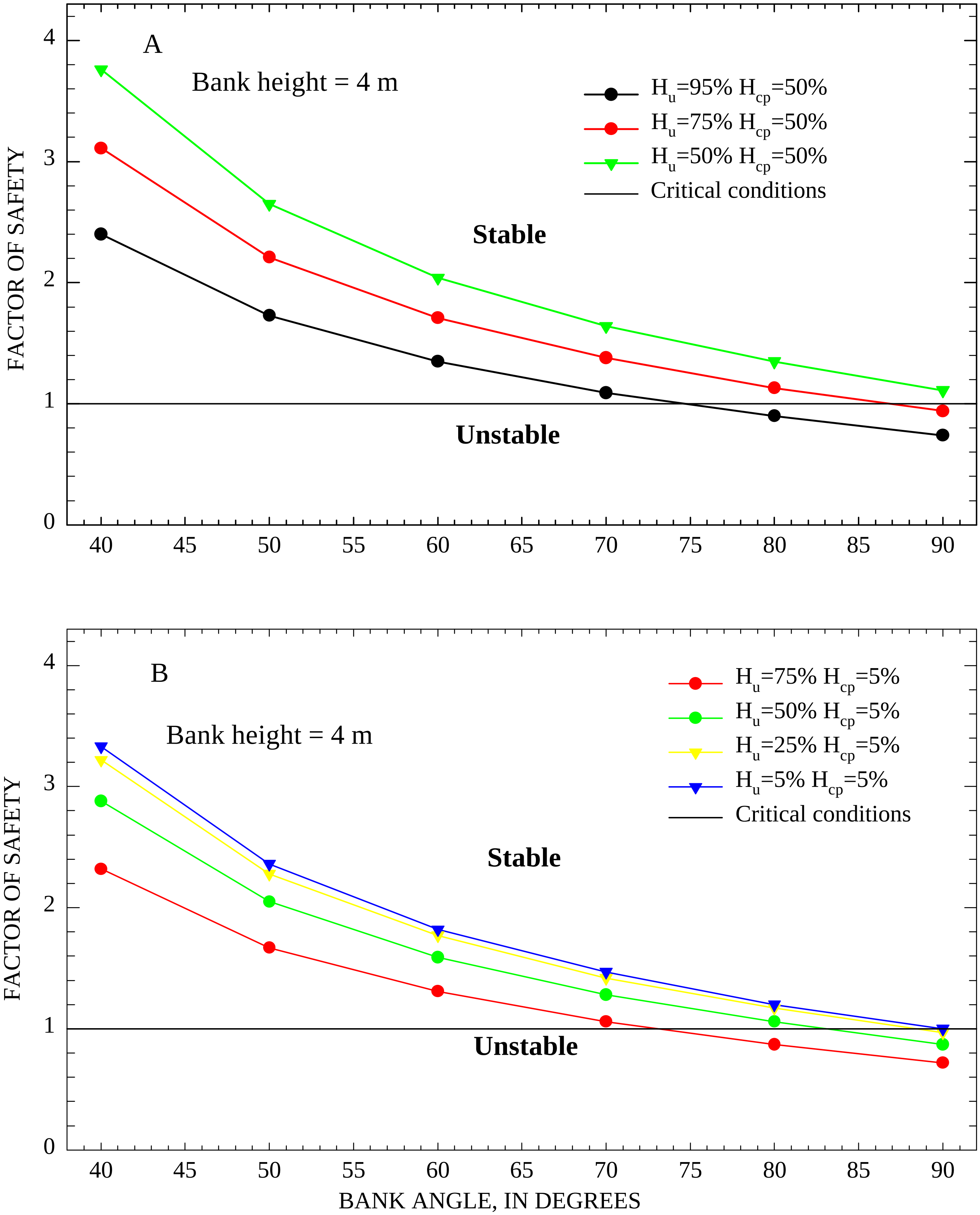


Figure 33-- Bank-stability conditions for 4 m banks for the lower Yalobusha River and Topashaw Creek under 1997 conditions (A), and under future conditions assuming removal of the debris jam (B). Note confining pressure (cp) and pore pressure (u) values are expressed in terms of heights relative to total bank height.

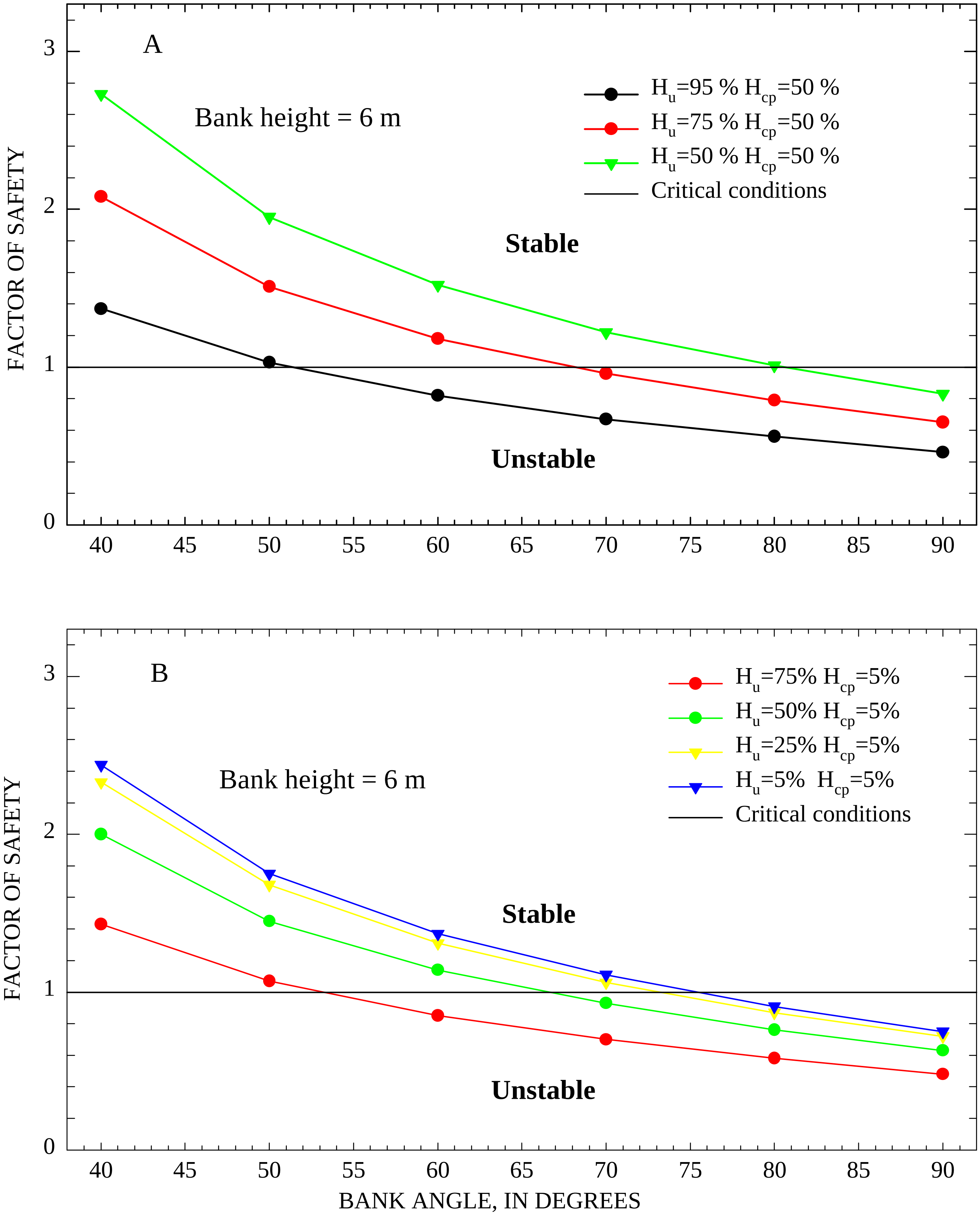
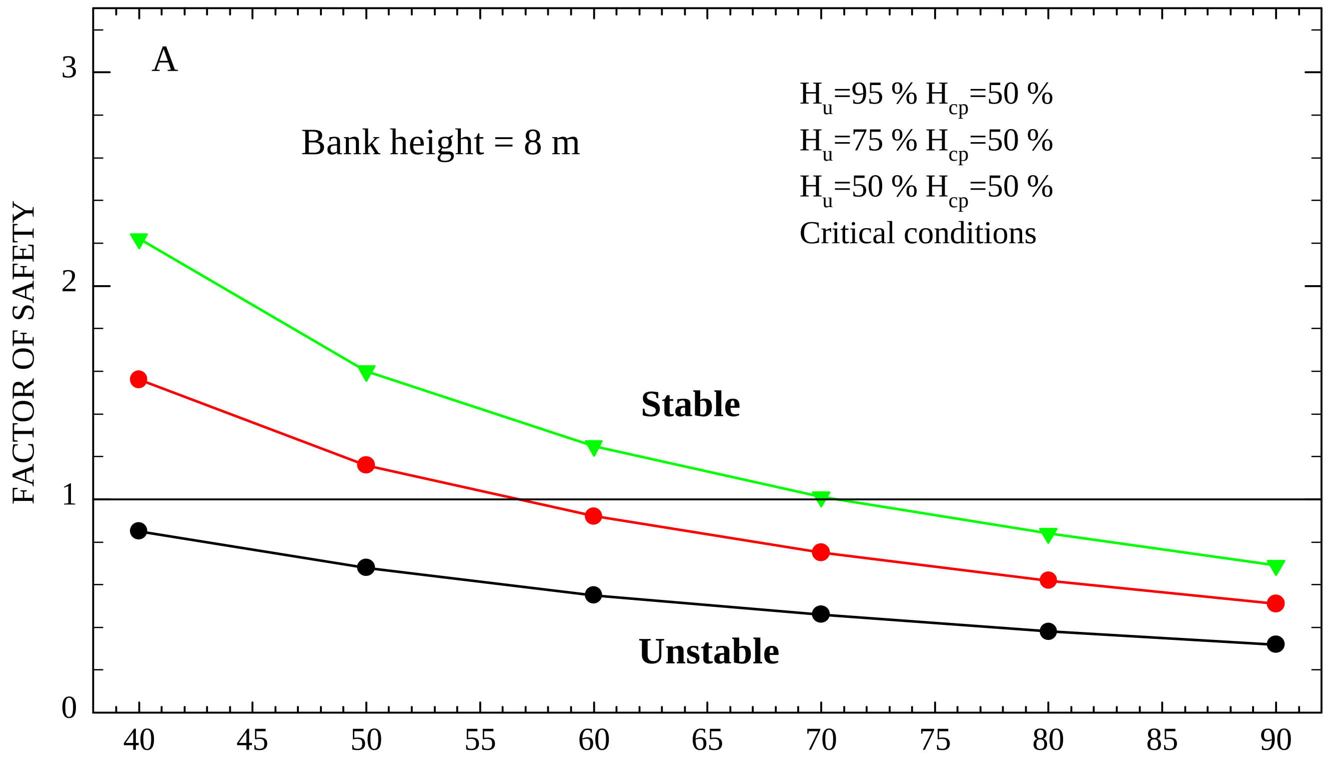


Figure 34-- Bank-stability conditions for 6m banks for the lower Yalobusha River and Topashaw Creek under 1997 conditions (A), and under future conditions assuming removal of the debris jam (B). Note confining pressure (cp) and pore pressure (u) values are expressed in terms of heights relative to total bank height.



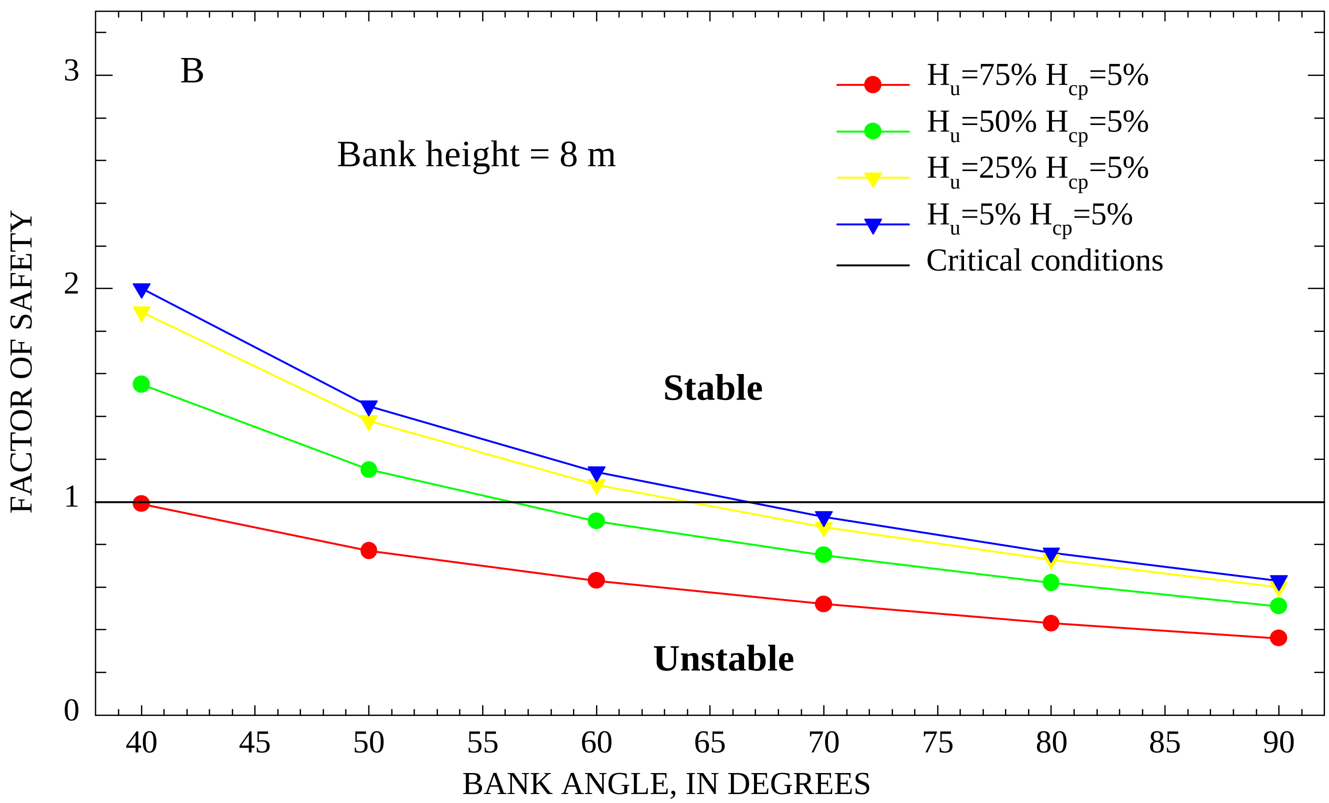


Figure 35-- Bank-stability conditions for 8 m banks for the lower Yalobusha River and Topashaw Creek under 1997 conditions (A), and under future conditions assuming removal of the debris jam (B). Note confining pressure (cp) and pore pressure (u) values are expressed in terms of heights relative to total bank height.

Table 14-- Factor of safety values for a range of pore and confining pressure conditions on the Yalobusha River and Topashaw Creek

River bank height = 4 m

Bank angle		H_{cp} = 5%	H_{cp} = 25%	H_{cp} = 50%	H_{cp} = 75%	H_{cp} = 95%
$\alpha = 40^o$	H_u = 5%	3.33	3.53	4.28	6.05	9.46
	H_u = 25%	3.22	3.42	4.16	5.90	9.24
	H_u = 50%	2.88	3.07	3.76	5.40	8.54
	H_u = 75%	2.32	2.49	3.11	4.58	7.39
	H_u = 95%	1.71	1.86	2.40	3.68	6.13
$\alpha = 50^o$	H_u = 5%	2.36	2.50	3.00	4.20	6.51
	H_u = 25%	2.28	2.42	2.92	4.10	6.36
	H_u = 50%	2.05	2.18	2.65	3.76	5.89
	H_u = 75%	1.67	1.79	2.21	3.20	5.11
	H_u = 95%	1.26	1.36	1.73	2.59	4.26
$\alpha = 60^o$	H_u = 5%	1.82	1.93	2.31	3.22	4.95
	H_u = 25%	1.77	1.87	2.25	3.13	4.84
	H_u = 50%	1.59	1.69	2.04	2.88	4.49
	H_u = 75%	1.31	1.39	1.71	2.46	3.90
	H_u = 95%	0.99	1.07	1.35	2.00	3.25
$\alpha = 70^o$	H_u = 5%	1.47	1.55	1.85	2.57	3.95
	H_u = 25%	1.42	1.50	1.80	2.51	3.86
	H_u = 50%	1.28	1.36	1.64	2.31	3.58
	H_u = 75%	1.06	1.13	1.38	1.97	3.11
	H_u = 95%	0.81	0.87	1.09	1.61	2.60
$\alpha = 80^o$	H_u = 5%	1.20	1.27	1.52	2.10	3.23
	H_u = 25%	1.17	1.23	1.48	2.05	3.15
	H_u = 50%	1.06	1.12	1.35	1.89	2.92
	H_u = 75%	0.87	0.93	1.13	1.61	2.54
	H_u = 95%	0.67	0.72	0.90	1.32	2.13
$\alpha = 90^o$	H_u = 5%	1.00	1.05	1.26	1.74	2.67
	H_u = 25%	0.97	1.02	1.22	1.70	2.61
	H_u = 50%	0.87	0.93	1.11	1.56	2.42
	H_u = 75%	0.72	0.77	0.94	1.34	2.10
	H_u = 95%	0.55	0.59	0.74	1.09	1.76

α =average bank angle

H_u =height of groundwater table relative to the total bank height, in percent

H_{cp} =height of surface water in channel relative to the total bank height, in percent

0.99 = red numbers denote unstable banks

Table 15-- Factor of safety values for a range of pore and confining pressure conditions on the Yalobusha River and Topashaw Creek

River bank height = 6 m

Bank angle		H_{cp} = 5%	H_{cp} = 25%	H_{cp} = 50%	H_{cp} = 75%	H_{cp} = 95%
$\alpha = 40^o$	H_u = 5%	2.44	2.62	3.25	4.75	7.64
	H_u = 25%	2.33	2.50	3.12	4.59	7.41
	H_u = 50%	2.00	2.15	2.73	4.10	6.72
	H_u = 75%	1.43	1.57	2.08	3.27	5.57
	H_u = 95%	0.82	0.94	1.37	2.37	4.31
$\alpha = 50^o$	H_u = 5%	1.75	1.87	2.30	3.32	5.28
	H_u = 25%	1.68	1.80	2.22	3.21	5.13
	H_u = 50%	1.45	1.56	1.95	2.88	4.66
	H_u = 75%	1.07	1.17	1.51	2.32	3.87
	H_u = 95%	0.66	0.74	1.03	1.71	3.02
$\alpha = 60^o$	H_u = 5%	1.37	1.46	1.78	2.55	4.02
	H_u = 25%	1.31	1.40	1.72	2.47	3.91
	H_u = 50%	1.14	1.22	1.52	2.22	3.56
	H_u = 75%	0.85	0.92	1.18	1.79	2.97
	H_u = 95%	0.54	0.60	0.82	1.33	2.32
$\alpha = 70^o$	H_u = 5%	1.11	1.18	1.43	2.04	3.21
	H_u = 25%	1.06	1.13	1.38	1.98	3.12
	H_u = 50%	0.93	0.99	1.22	1.78	2.84
	H_u = 75%	0.70	0.75	0.96	1.44	2.37
	H_u = 95%	0.45	0.50	0.67	1.08	1.86
$\alpha = 80^o$	H_u = 5%	0.91	0.97	1.18	1.67	2.62
	H_u = 25%	0.87	0.93	1.14	1.62	2.55
	H_u = 50%	0.76	0.82	1.01	1.46	2.32
	H_u = 75%	0.58	0.62	0.79	1.18	1.94
	H_u = 95%	0.38	0.41	0.56	0.89	1.53
$\alpha = 90^o$	H_u = 5%	0.75	0.80	0.97	1.38	2.17
	H_u = 25%	0.72	0.77	0.94	1.34	2.11
	H_u = 50%	0.63	0.68	0.83	1.21	1.92
	H_u = 75%	0.48	0.52	0.65	0.98	1.61
	H_u = 95%	0.31	0.34	0.46	0.74	1.26

α =average bank angle

H_u =height of groundwater table relative to the total bank height, in percent

H_{cp} =height of surface water in channel relative to the total bank height, in percent

0.82 = red numbers denote unstable banks

Table 16--Factor of safety values for a range of pore and confining pressure conditions on the Yalobusha River and Topashaw Creek

River bank height = 8 m

Bank angle		H_{cp} = 5%	H_{cp} = 25%	H_{cp} = 50%	H_{cp} = 75%	H_{cp} = 95%
$\alpha = 40^o$	H_u = 5%	2.00	2.16	2.73	4.10	6.72
	H_u = 25%	1.89	2.04	2.61	3.94	6.50
	H_u = 50%	1.55	1.70	2.22	3.45	5.81
	H_u = 75%	0.99	1.11	1.56	2.62	4.66
	H_u = 95%	0.38	0.48	0.85	1.72	3.40
$\alpha = 50^o$	H_u = 5%	1.45	1.56	1.95	2.88	4.66
	H_u = 25%	1.38	1.49	1.87	2.77	4.51
	H_u = 50%	1.15	1.25	1.60	2.44	4.04
	H_u = 75%	0.77	0.85	1.16	1.88	3.26
	H_u = 95%	0.36	0.42	0.68	1.27	2.40
$\alpha = 60^o$	H_u = 5%	1.14	1.22	1.51	2.21	3.54
	H_u = 25%	1.08	1.16	1.45	2.13	3.43
	H_u = 50%	0.91	0.99	1.25	1.88	3.07
	H_u = 75%	0.63	0.69	0.92	1.46	2.49
	H_u = 95%	0.31	0.37	0.55	1.00	1.85
$\alpha = 70^o$	H_u = 5%	0.93	0.99	1.22	1.78	2.84
	H_u = 25%	0.88	0.95	1.17	1.71	2.75
	H_u = 50%	0.75	0.80	1.01	1.51	2.47
	H_u = 75%	0.52	0.57	0.75	1.18	2.00
	H_u = 95%	0.27	0.31	0.46	0.81	1.49
$\alpha = 80^o$	H_u = 5%	0.76	0.82	1.01	1.46	2.32
	H_u = 25%	0.73	0.78	0.97	1.41	2.25
	H_u = 50%	0.62	0.66	0.84	1.24	2.02
	H_u = 75%	0.43	0.47	0.62	0.97	1.64
	H_u = 95%	0.23	0.26	0.38	0.67	1.23
$\alpha = 90^o$	H_u = 5%	0.63	0.68	0.83	1.21	1.92
	H_u = 25%	0.60	0.65	0.80	1.16	1.86
	H_u = 50%	0.51	0.55	0.69	1.03	1.67
	H_u = 75%	0.36	0.39	0.51	0.80	1.36
	H_u = 95%	0.19	0.22	0.32	0.56	1.02

α =average bank angle

H_u =height of groundwater table relative to the total bank height, in percent

H_{cp} =height of surface water in channel relative to the total bank height, in percent

0.99 = red numbers denote unstable banks

Table 17-- Factor of safety values for a range of pore and confining pressure conditions on the Yalobusha River and Topashaw Creek

River bank height = 10 m

Bank angle		H_{cp} = 5%	H_{cp} = 25%	H_{cp} = 50%	H_{cp} = 75%	H_{cp} = 95%
α = 40º	H_u = 5%	1.73	1.88	2.42	3.71	6.18
	H_u = 25%	1.62	1.77	2.30	3.55	5.96
	H_u = 50%	1.29	1.42	1.91	3.06	5.26
	H_u = 75%	0.72	0.84	1.25	2.23	4.11
	H_u = 95%	-	-	0.54	1.33	2.85
α = 50º	H_u = 5%	1.27	1.37	1.74	2.62	4.29
	H_u = 25%	1.20	1.30	1.66	2.51	4.14
	H_u = 50%	0.97	1.06	1.39	2.17	3.67
	H_u = 75%	0.59	0.67	0.95	1.61	2.89
	H_u = 95%	-	0.24	0.47	1.00	2.03
α = 60º	H_u = 5%	1.01	1.08	1.36	2.02	3.28
	H_u = 25%	0.95	1.02	1.30	1.94	3.17
	H_u = 50%	0.78	0.85	1.09	1.68	2.81
	H_u = 75%	0.49	0.55	0.76	1.26	2.22
	H_u = 95%	0.18	0.22	0.40	0.80	1.58
α = 70º	H_u = 5%	0.82	0.88	1.10	1.62	2.62
	H_u = 25%	0.77	0.83	1.05	1.56	2.53
	H_u = 50%	0.64	0.69	0.89	1.36	2.25
	H_u = 75%	0.41	0.46	0.62	1.02	1.78
	H_u = 95%	0.16	0.20	0.34	0.66	1.27
α = 80º	H_u = 5%	0.68	0.73	0.90	1.33	2.14
	H_u = 25%	0.64	0.69	0.86	1.28	2.07
	H_u = 50%	0.53	0.57	0.73	1.11	1.84
	H_u = 75%	0.34	0.38	0.52	0.84	1.46
	H_u = 95%	0.14	0.17	0.28	0.54	1.05
α = 90º	H_u = 5%	0.56	0.60	0.75	1.10	1.77
	H_u = 25%	0.53	0.57	0.72	1.06	1.71
	H_u = 50%	0.44	0.48	0.61	0.92	1.52
	H_u = 75%	0.29	0.32	0.43	0.70	1.21
	H_u = 95%	0.12	0.14	0.24	0.45	0.87

α = average bank angle

H_u =height of groundwater table relative to the total bank height, in percent

H_{cp} =height of surface water in channel relative to the total bank height, in percen

0.72 = red numbers denote unstable banks

Table 18-- Factor of safety values for a range of pore and confining pressure conditions on the tributaries with stream banks containing clay, silt, and sand

River bank height = 4 m

Bank angle		H_{cp} = 5%	H_{cp} = 25%	H_{cp} = 50%	H_{cp} = 75%	H_{cp} = 95%
$\alpha = 40^o$	H_u = 5%	3.07	3.33	4.31	6.64	11.26
	H_u = 25%	2.89	3.15	4.10	6.38	10.89
	H_u = 50%	2.34	2.58	3.46	5.56	9.72
	H_u = 75%	1.43	1.63	2.39	4.20	7.78
	H_u = 95%	-	0.6	1.22	2.72	5.66
$\alpha = 50^o$	H_u = 5%	2.04	2.20	2.79	4.22	7.03
	H_u = 25%	1.93	2.09	2.67	4.06	6.80
	H_u = 50%	1.60	1.74	2.28	3.56	6.09
	H_u = 75%	1.04	1.16	1.62	2.73	4.91
	H_u = 95%	0.43	0.54	0.92	1.82	3.62
$\alpha = 60^o$	H_u = 5%	1.54	1.66	2.09	3.12	5.15
	H_u = 25%	1.47	1.58	2.00	3.00	4.98
	H_u = 50%	1.23	1.33	1.72	2.64	4.47
	H_u = 75%	0.82	0.91	1.25	2.04	3.61
	H_u = 95%	0.39	0.46	0.73	1.39	2.68
$\alpha = 70^o$	H_u = 5%	1.22	1.31	1.64	2.42	3.95
	H_u = 25%	1.16	1.25	1.57	2.33	3.82
	H_u = 50%	0.98	1.06	1.35	2.06	3.43
	H_u = 75%	0.67	0.74	0.99	1.60	2.79
	H_u = 95%	0.33	0.39	0.60	1.10	2.08
$\alpha = 80^o$	H_u = 5%	1.00	1.07	1.33	1.96	3.19
	H_u = 25%	0.95	1.02	1.28	1.89	3.09
	H_u = 50%	0.80	0.87	1.10	1.67	2.77
	H_u = 75%	0.55	0.61	0.81	1.30	2.25
	H_u = 95%	0.28	0.33	0.50	0.90	1.69
$\alpha = 90^o$	H_u = 5%	0.82	0.88	1.09	1.61	2.61
	H_u = 25%	0.78	0.84	1.05	1.55	2.53
	H_u = 50%	0.66	0.71	0.91	1.37	2.27
	H_u = 75%	0.46	0.50	0.67	1.07	1.85
	H_u = 95%	0.24	0.27	0.41	0.74	1.38

α =average bank angle

H_u =height of groundwater table relative to the total bank height, in percent

H_{cp} =height of surface water in channel relative to the total bank height, in percent

0.6 = red numbers denote unstable banks

Table 19-- Factor of safety values for a range of pore and confining pressure conditions on the tributaries with stream banks containing clay, silt, and sand

River bank height = 6 m

Bank angle		H_{cp} = 5%	H_{cp} = 25%	H_{cp} = 50%	H_{cp} = 75%	H_{cp} = 95%
$\alpha = 40^o$	H_u = 5%	2.30	2.54	3.41	5.50	9.63
	H_u = 25%	2.12	2.35	3.20	5.23	9.25
	H_u = 50%	1.57	1.79	2.56	4.42	8.09
	H_u = 75%	0.66	0.84	1.49	3.05	6.14
	H_u = 95%	-	-	-	1.57	4.03
$\alpha = 50^o$	H_u = 5%	1.57	1.71	2.24	3.52	6.03
	H_u = 25%	1.46	1.60	2.12	3.36	5.81
	H_u = 50%	1.13	1.26	1.73	2.86	5.10
	H_u = 75%	0.57	0.68	1.08	2.03	3.91
	H_u = 95%	-	-	0.37	1.13	2.62
$\alpha = 60^o$	H_u = 5%	1.21	1.31	1.69	2.61	4.43
	H_u = 25%	1.13	1.23	1.60	2.50	4.26
	H_u = 50%	0.89	0.98	1.32	2.14	3.75
	H_u = 75%	0.49	0.56	0.85	1.54	2.90
	H_u = 95%	-	-	0.34	0.89	1.97
$\alpha = 70^o$	H_u = 5%	0.97	1.05	1.35	2.06	3.47
	H_u = 25%	0.91	0.99	1.28	1.97	3.34
	H_u = 50%	0.72	0.79	1.06	1.69	2.94
	H_u = 75%	0.41	0.47	0.69	1.23	2.28
	H_u = 95%	-	0.12	0.30	0.72	1.56
$\alpha = 80^o$	H_u = 5%	0.79	0.86	1.10	1.67	2.80
	H_u = 25%	0.75	0.81	1.04	1.60	2.70
	H_u = 50%	0.59	0.65	0.86	1.37	2.38
	H_u = 75%	0.34	0.39	0.57	1.00	1.85
	H_u = 95%	0.07	0.11	0.25	0.59	1.27
$\alpha = 90^o$	H_u = 5%	0.65	0.71	0.90	1.37	2.29
	H_u = 25%	0.61	0.67	0.86	1.31	2.21
	H_u = 50%	0.49	0.54	0.71	1.13	1.95
	H_u = 75%	0.29	0.33	0.47	0.82	1.51
	H_u = 95%	0.06	0.09	0.21	0.49	1.04

α =average bank angle

H_u =height of groundwater table relative to the total bank height, in percent

H_{cp} =height of surface water in channel relative to the total bank height, in percent

0.66 = red numbers denote unstable banks

Table 20-- Factor of safety values for a range of pore and confining pressure conditions on the tributaries with stream banks containing clay, silt, and sand

River bank height = 8 m

Bank angle		H_{cp} = 5%	H_{cp} = 25%	H_{cp} = 50%	H_{cp} = 75%	H_{cp} = 95%
α = 40°	H_u = 5%	1.91	2.14	2.96	4.92	8.81
	H_u = 25%	1.74	1.96	2.75	4.66	8.44
	H_u = 50%	1.19	1.39	2.11	3.84	7.27
	H_u = 75%	-	-	1.04	2.48	5.33
	H_u = 95%	-	-	-	1.00	3.21
α = 50°	H_u = 5%	1.33	1.47	1.97	3.17	5.54
	H_u = 25%	1.23	1.36	1.85	3.01	5.31
	H_u = 50%	0.89	1.01	1.45	2.51	4.60
	H_u = 75%	0.34	0.44	0.80	1.68	3.41
	H_u = 95%	-	-	-	0.78	2.13
α = 60°	H_u = 5%	1.04	1.14	1.50	2.36	4.07
	H_u = 25%	0.96	1.06	1.41	2.25	3.90
	H_u = 50%	0.72	0.81	1.12	1.89	3.39
	H_u = 75%	0.32	0.39	0.65	1.29	2.54
	H_u = 95%	-	-	-	0.63	1.61
α = 70°	H_u = 5%	0.84	0.91	1.19	1.86	3.19
	H_u = 25%	0.78	0.85	1.12	1.77	3.06
	H_u = 50%	0.59	0.66	0.90	1.50	2.66
	H_u = 75%	0.28	0.34	0.54	1.03	2.00
	H_u = 95%	-	-	0.14	0.53	1.28
α = 80°	H_u = 5%	0.69	0.75	0.97	1.51	2.58
	H_u = 25%	0.64	0.70	0.92	1.44	2.47
	H_u = 50%	0.49	0.54	0.74	1.22	2.15
	H_u = 75%	0.24	0.28	0.45	0.84	1.62
	H_u = 95%	-	-	0.13	0.44	1.04
α = 90°	H_u = 5%	0.56	0.61	0.79	1.23	2.07
	H_u = 25%	0.53	0.57	0.75	1.17	1.99
	H_u = 50%	0.40	0.45	0.61	0.99	1.74
	H_u = 75%	0.20	0.24	0.37	0.69	1.31
	H_u = 95%	-	-	0.11	0.36	0.85

α =average bank angle

H_u =height of groundwater table relative to the total bank height, in percent

H_{cp} =height of surface water in channel relative to the total bank height, in percent

0.89 = red numbers denote unstable banks

50 or 75%. For the long-term low-flow case, bank-stability conditions are similar to those under current low-flow conditions where H_u and H_{cp} values are 50% (compare green lines on Figures 33A-35A with the blue lines on Figures 33B-35B). If, however, plug removal involves the quick draining of water from the channel, a condition of rapid drawdown will occur where the confining pressure in the channel will not equally counteract pore-water pressures in the banks. Under these conditions, instability is induced at lower bank angles, (representing a larger percentage of the banks in these reaches) for the $H_u = 50\%$ and 75% cases (Figures 33B-35B). For 8 m banks, all bank slopes in the are unstable if pore pressures reach $H_u = 75\%$ during rapid draining of the plug (Figure 35B). Clearly, considerable care should be exercised if mitigation measures call for removal of the plug to insure that drainage occurs slowly. It would be advisable, therefore, to remove the obstruction slowly in order to maintain the groundwater at the same level as the river stage. A more thorough comparison of long-term and rapid-drawdown bank-stability conditions during plug removal can be obtained from the data shown in Tables 14-16. Unstable conditions are shown in red.

Conditions along Middle and Upper Reaches of Yalobusha River and Topashaw Creek

Channel banks in these reaches are characterized by high bank heights and low confining pressures, making for generally unstable conditions. This is reflected in that most of these reaches are stage IV reaches. At bank heights of 10 m, slopes greater than 60° are unstable, even under relatively dry conditions ($H_u = 5\%$ or 25% with $H_{cp} = 5\%$; Figure 36). Banks 8 m-high are stable only for low angles and low values of pore-water pressure. Under the worst hydrologic conditions, these banks are almost always unstable. Because of the similar geotechnical properties between these reaches and tributary reaches that do not contain a sand unit, results from the middle and upper reaches of Yalobusha River and Topashaw Creek can be used to represent degraded tributaries. Tables 15-17 provide specific results of these bank-stability analyses for various combinations of bank heights, angles, and hydrologic conditions. Again, unstable conditions are denoted with red type.

Bank-stability conditions will tend to deteriorate with time at the uppermost end of the study reaches due to continued degradation and the consequent increase in bank heights. The effects of this can be appraised by viewing the F_s graph with the next greater bank height.

Conditions along Tributaries Containing a Sand Unit

Banks of these tributaries, represented by Cane, Duncan, Huffman, and Meridian Creeks tend to be the weakest in the watershed when considering equal bank heights, angles and hydrologic conditions. F_s results are shown graphically in Figure 37. Note that at 8-m bank heights, banks are predominantly unstable. Stable conditions are achieved only when the banks are dry. Conversely, banks 4 m-high generally are stable, except under conditions of high pore-water pressures ($H_u = 50\%$) and bank angles steeper than 70° (Figure 37). Data for all combinations of bank height, angle, and hydrology are shown in Tables 18-20.

PLANFORM CHANGES

Changes in the planform of a stream can involve numerous processes including bank failures, bed erosion, channel filling, and avulsion during floods. Observable changes in the course

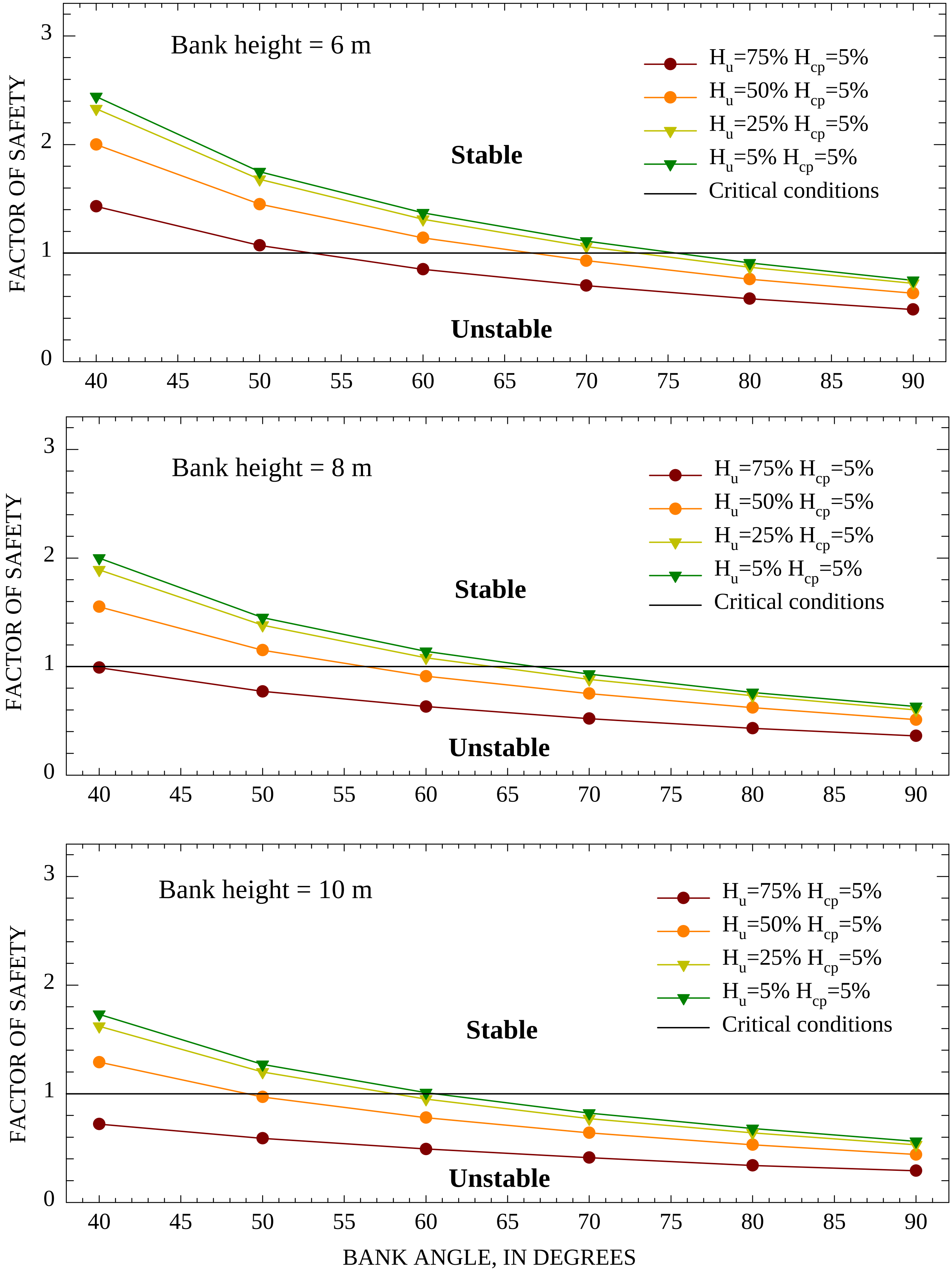


Figure 36-- Bank-stability conditions for the middle and upper part of theYalobusha River and Topashaw Creek under 1997 conditions.

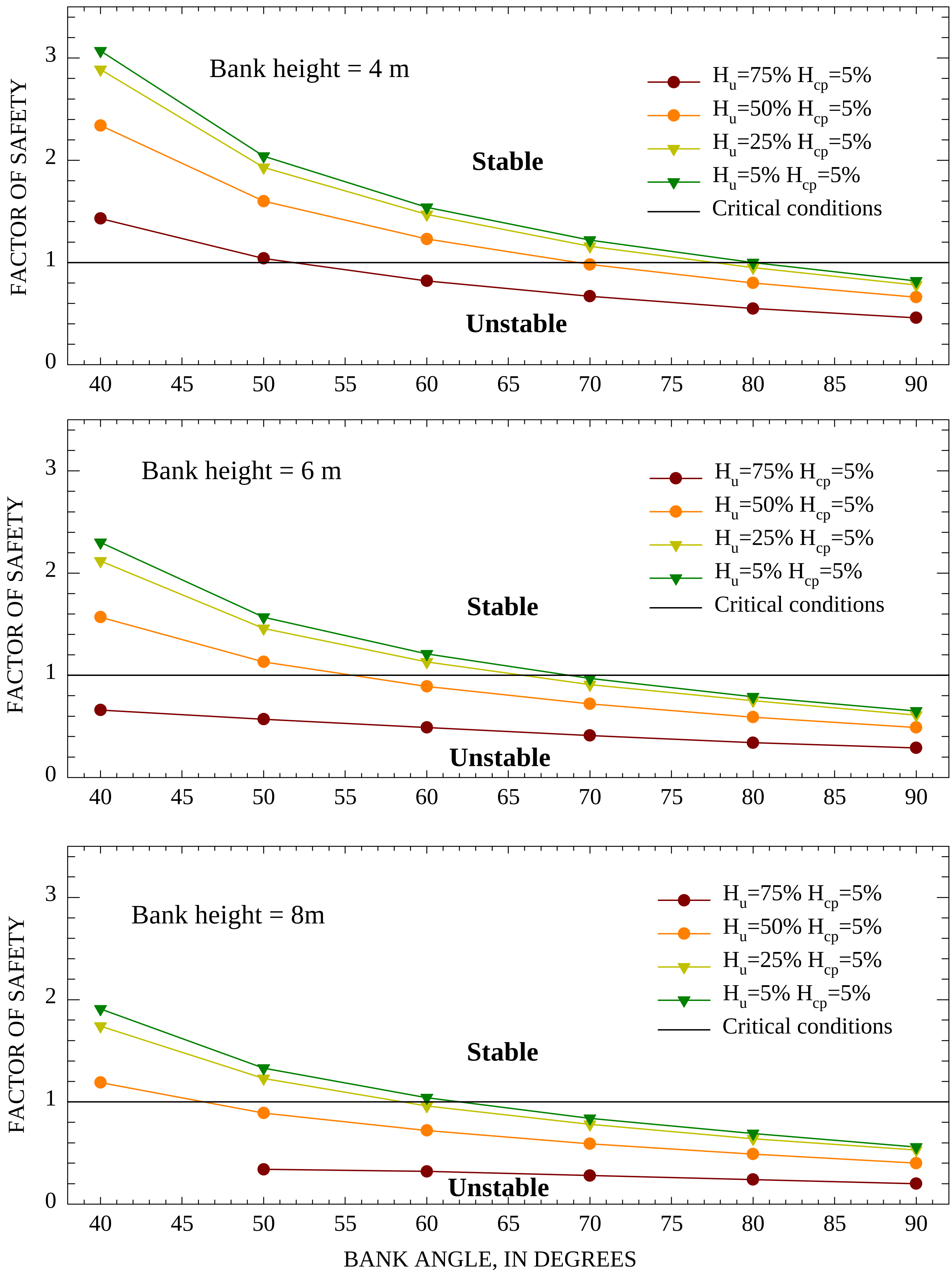


Figure 37-- Bank-stability conditions for tributaries of the Yalobusha River System with stream banks containing clay, silt, and sand.

Blank for figure 38

of the Yalobusha River downstream from Calhoun City can be documented for at least 100 years. These changes do not refer to those imposed directly on the channels by engineering works as described earlier. Maps surveyed in 1832 of the lands ceded by the Choctaw and Chickasaw Indians were used to identify the general course of the river in 1832. Some of the stream courses drawn on these 1832 maps, however, seem idealized. Series of aerial photographs taken in 1937, 1951, and 1969 were used to document channel locations for these periods.

The lower Yalobusha River has apparently avulsed several times across its flood plain in the past 100 years (Figure 38). These avulsions and several meander shifts probably occurred during periods of high flow before the construction of Grenada Lake. At present (1997) in the area just above the sediment/debris plug, the river spills onto its flood plain through breaches in its levee on both the north and south sides of the river. There is some evidence that much of the flow of the Yalobusha River becomes concentrated in a previously abandoned channel which flows along the bluff bordering the river's flood plain to the south. This course was traced from where the downstream-most section of this channel re-enters the Yalobusha River to a point upstream where it intersects Shutispear Creek. The channel is blocked at this point and splits into a number of distributary channels. A direct link to the Yalobusha River, therefore, could not be ascertained. However, it seems likely that the flow in this previously abandoned channel does represent a good proportion of the flow of the Yalobusha River.

SUMMARY OF GEOMORPHIC CONDITIONS IN THE YALOBUSHA RIVER SYSTEM

The Yalobusha River System experiences deposition and flooding problems in downstream reaches and erosion via headward-progressing knickpoints and massive bank failures in upper reaches. Although these general patterns are found throughout the region, and are associated with the consequences of accelerated erosion stemming from land mismanagement and channelization, the Yalobusha River System is unique because of the presence of resistant clay beds. Major features of the river system include: (1) almost an entire channelized stream network; (2) the straightened and enlarged Yalobusha River main stem terminates in an unmodified, sinuous reach with a much smaller cross section and conveyance; (3) the lower end of this channelized reach is completely blocked by a plug of sediment and debris; and (4) relatively erosion-resistant cohesive streambeds occur over much of the watershed.

The sediment/debris plug on the lower Yalobusha River is of critical importance to channel-adjustment processes and conditions in the river system by serving as a blockage to the downstream transport of sediment. For example, the conveyance of the 1967 modified channel was about an order of magnitude greater than the meandering reach downstream, and assuming a d_{50} = 0.4 mm, its sediment transport capacity was about two orders of magnitude greater. A discharge of 570 m^3/s could be passed through the channelized reach, but as flow entered the meandering reach, only about 70 m^3/s would remain in the channel, and the rest would spread across the flood plain.

The resistant clay beds have restricted advancement of knickpoints and knickzones in certain reaches and have caused a shift in the locus of channel adjustment to bank failures and channel widening. At least 85% of the channel material emanating from the Yalobusha River System is derived from the channel banks (Table 11). With the knowledge that bank failures do not occur during high flows but on the recessional limbs of storm hydrographs or even later,

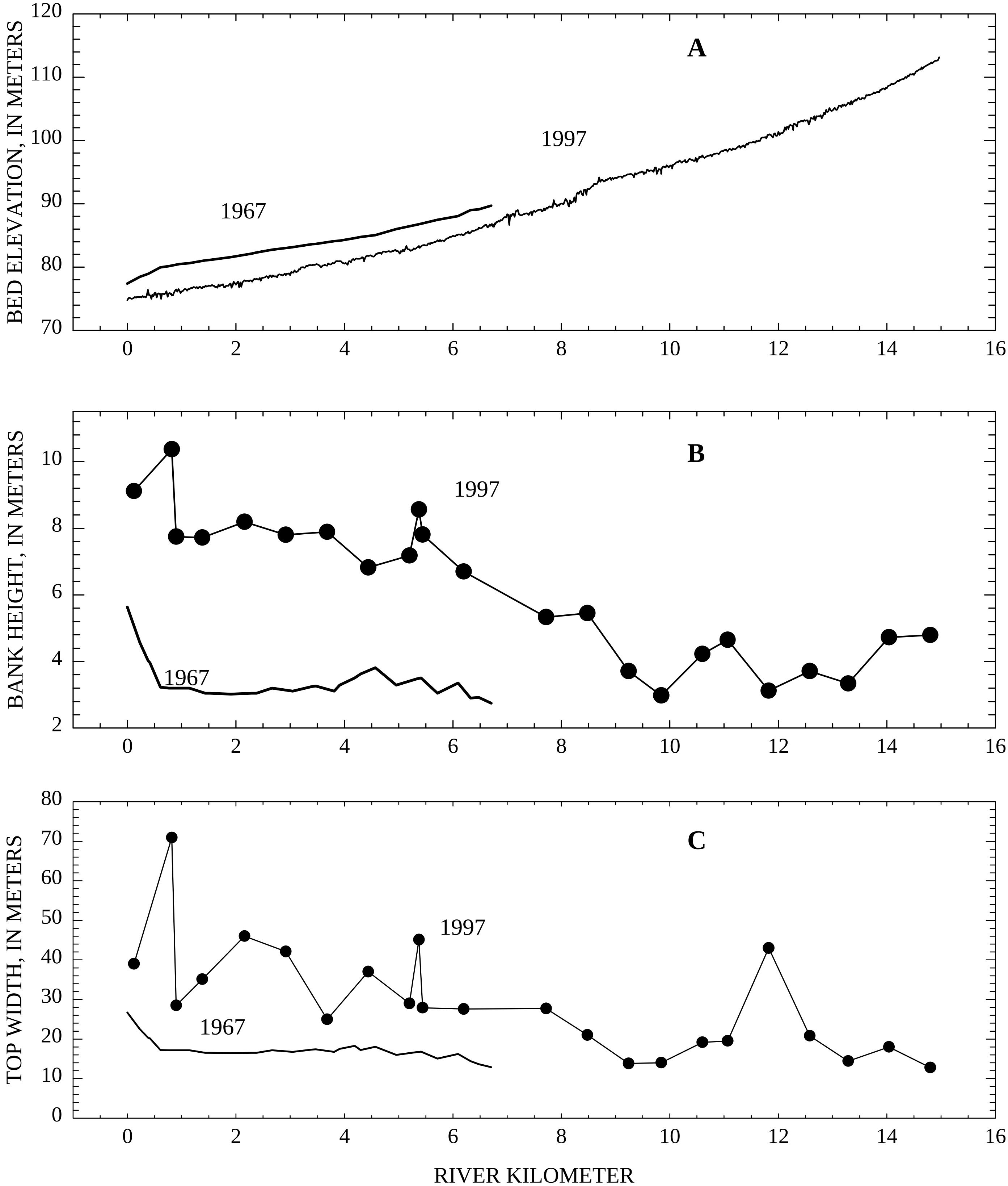


Figure 39--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Bear Creek.

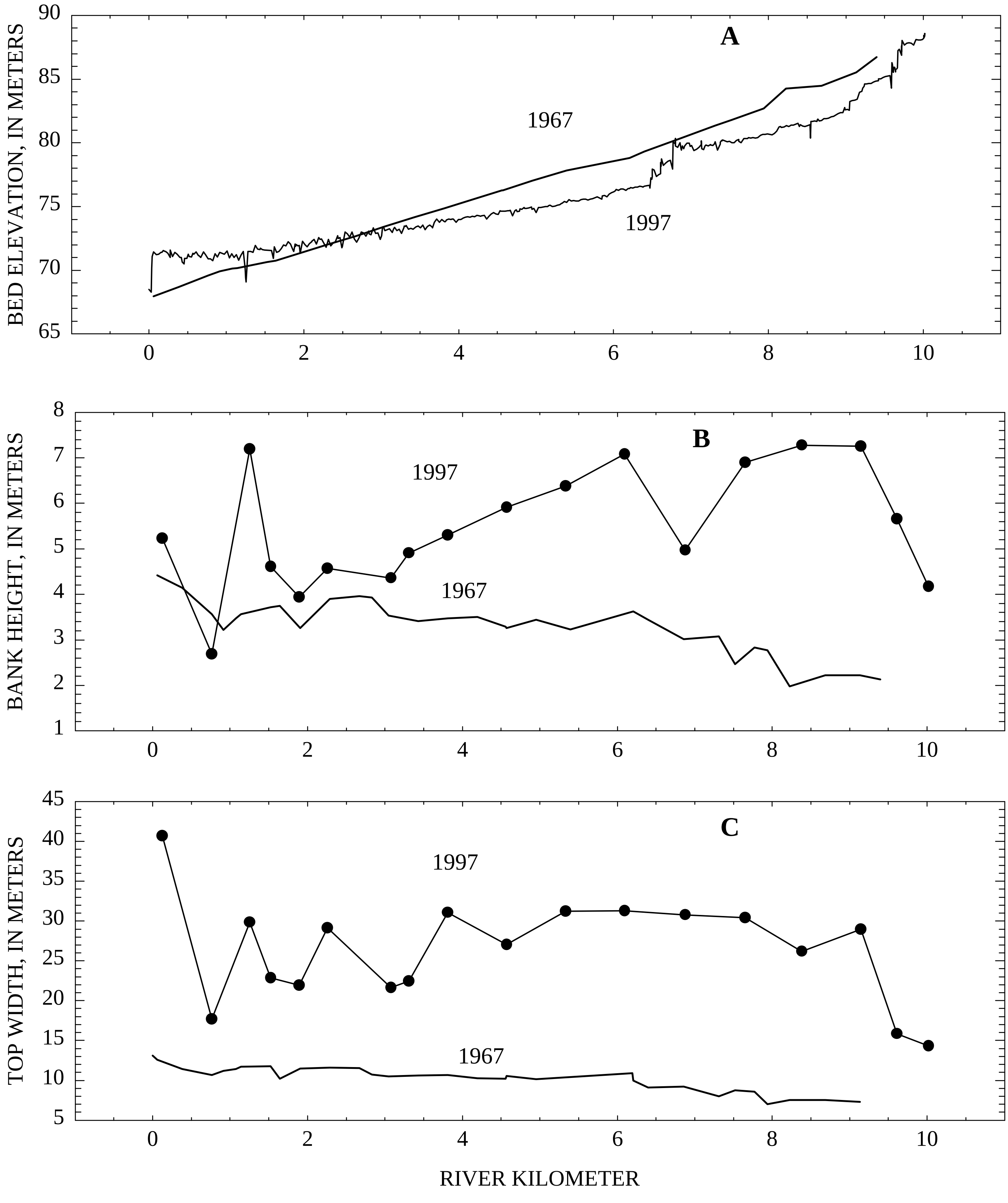


Figure 40--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Big Creek.

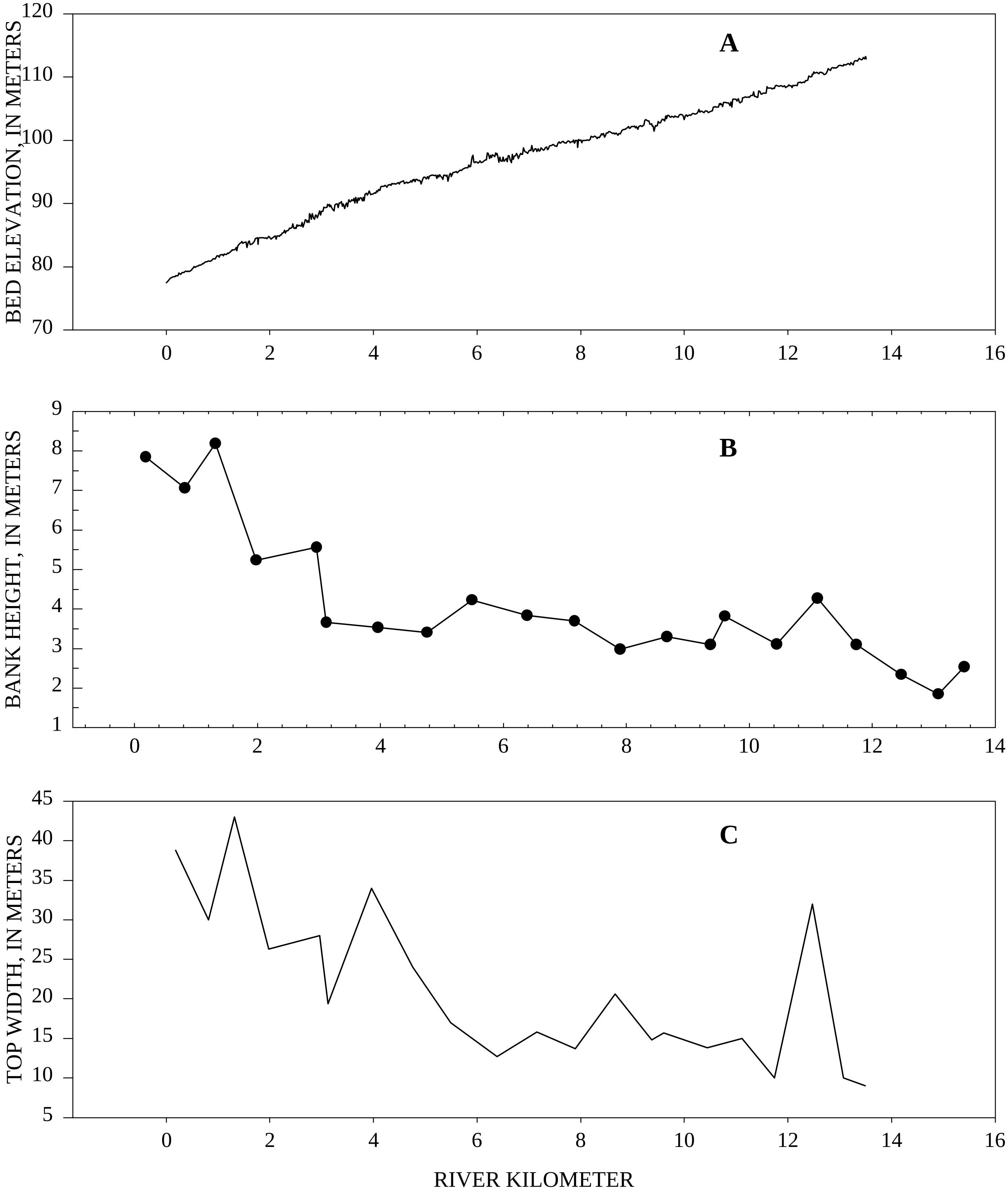


Figure 41--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Buck Creek.

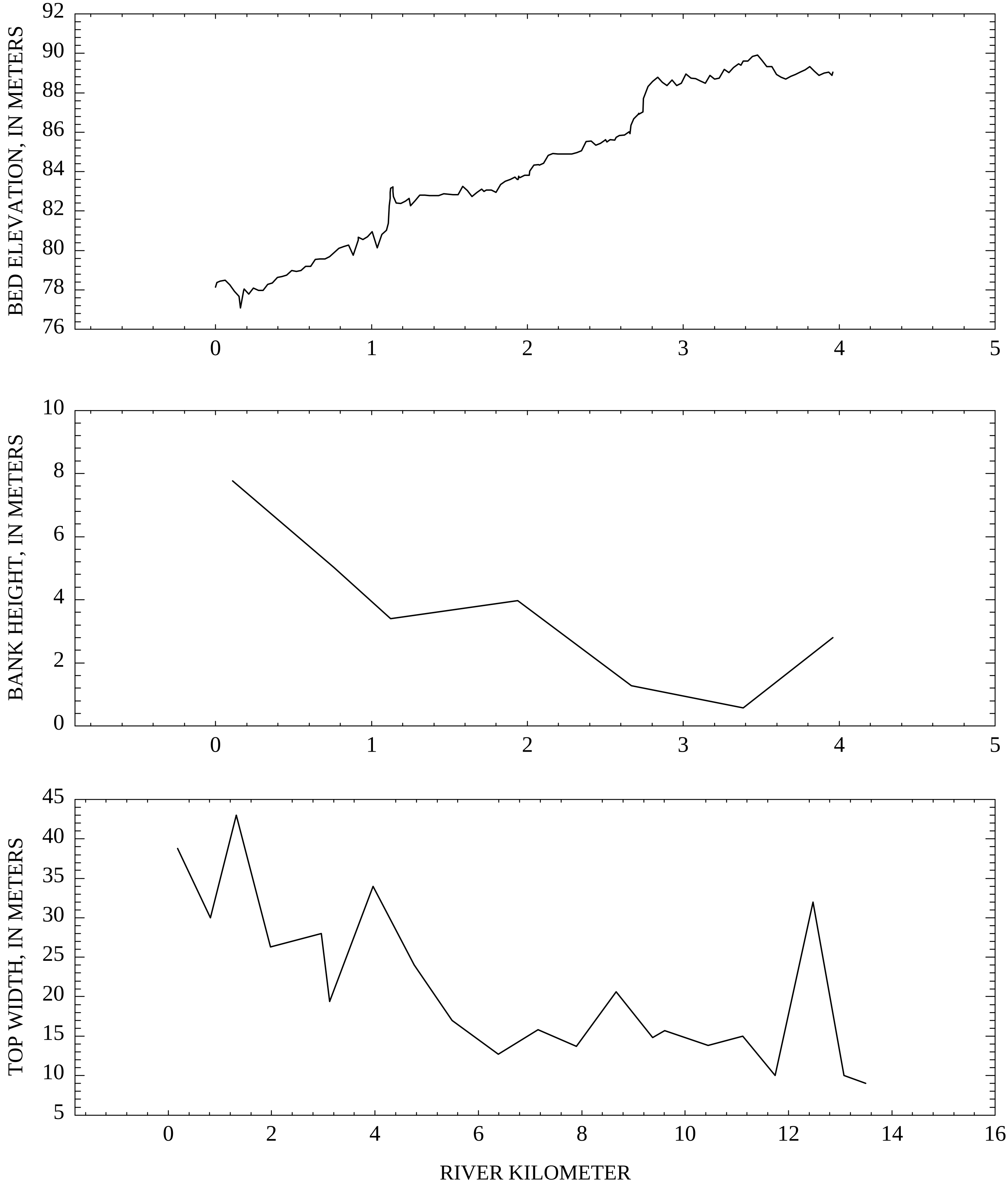


Figure 42--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Bull Creek.

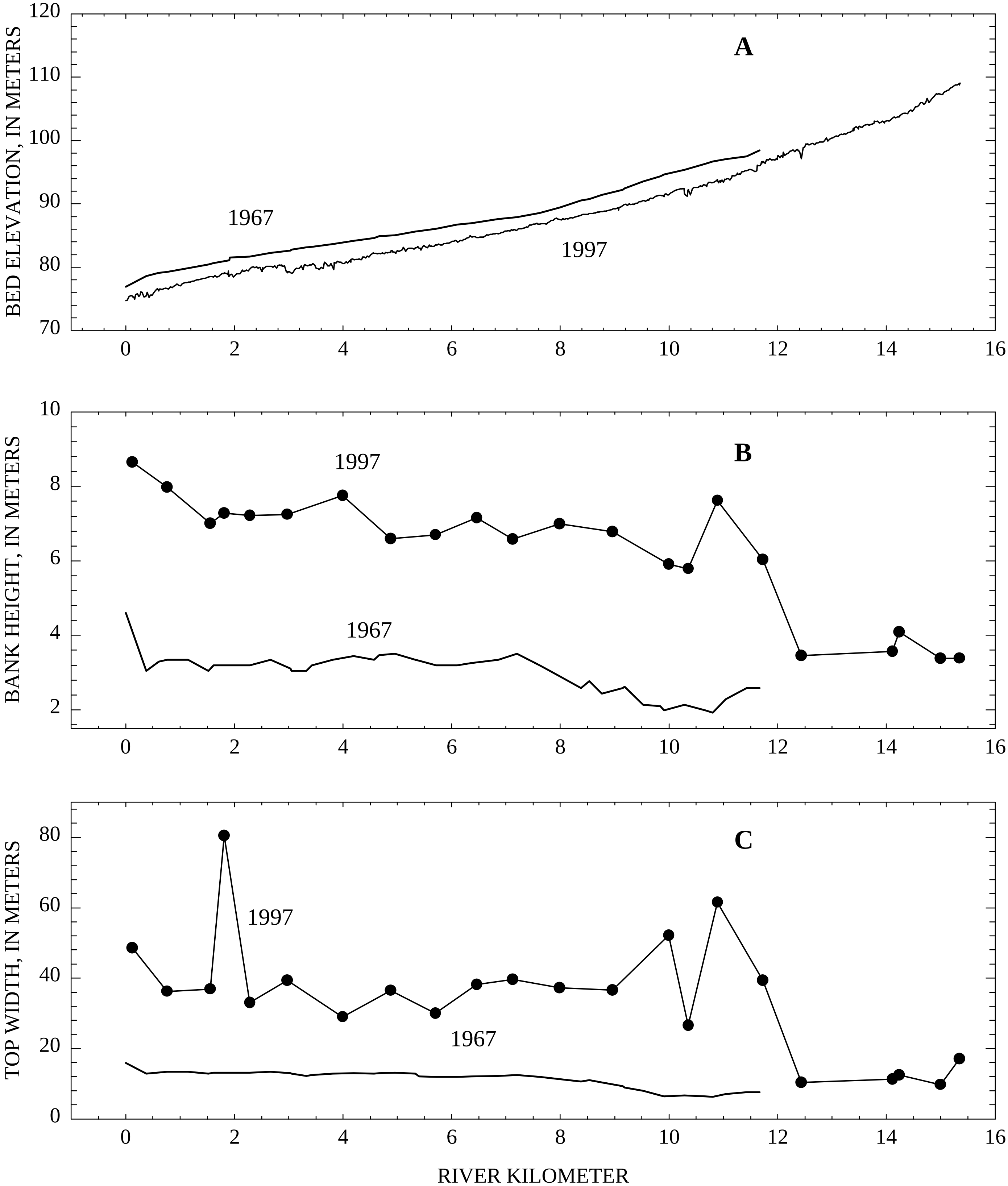


Figure 43--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Cane (Cook) Creek.

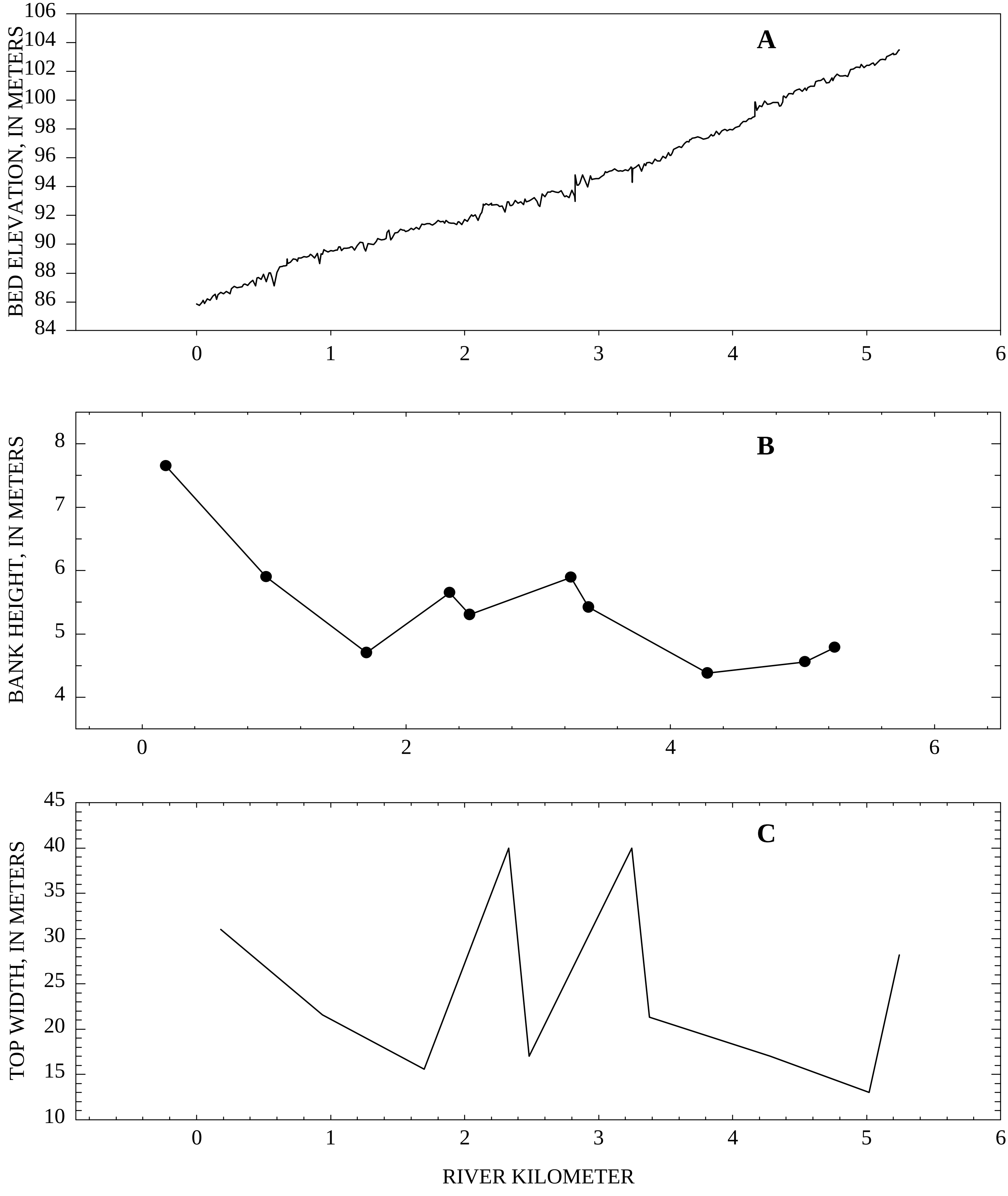


Figure 44--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Dry Creek (Topashaw Basin)

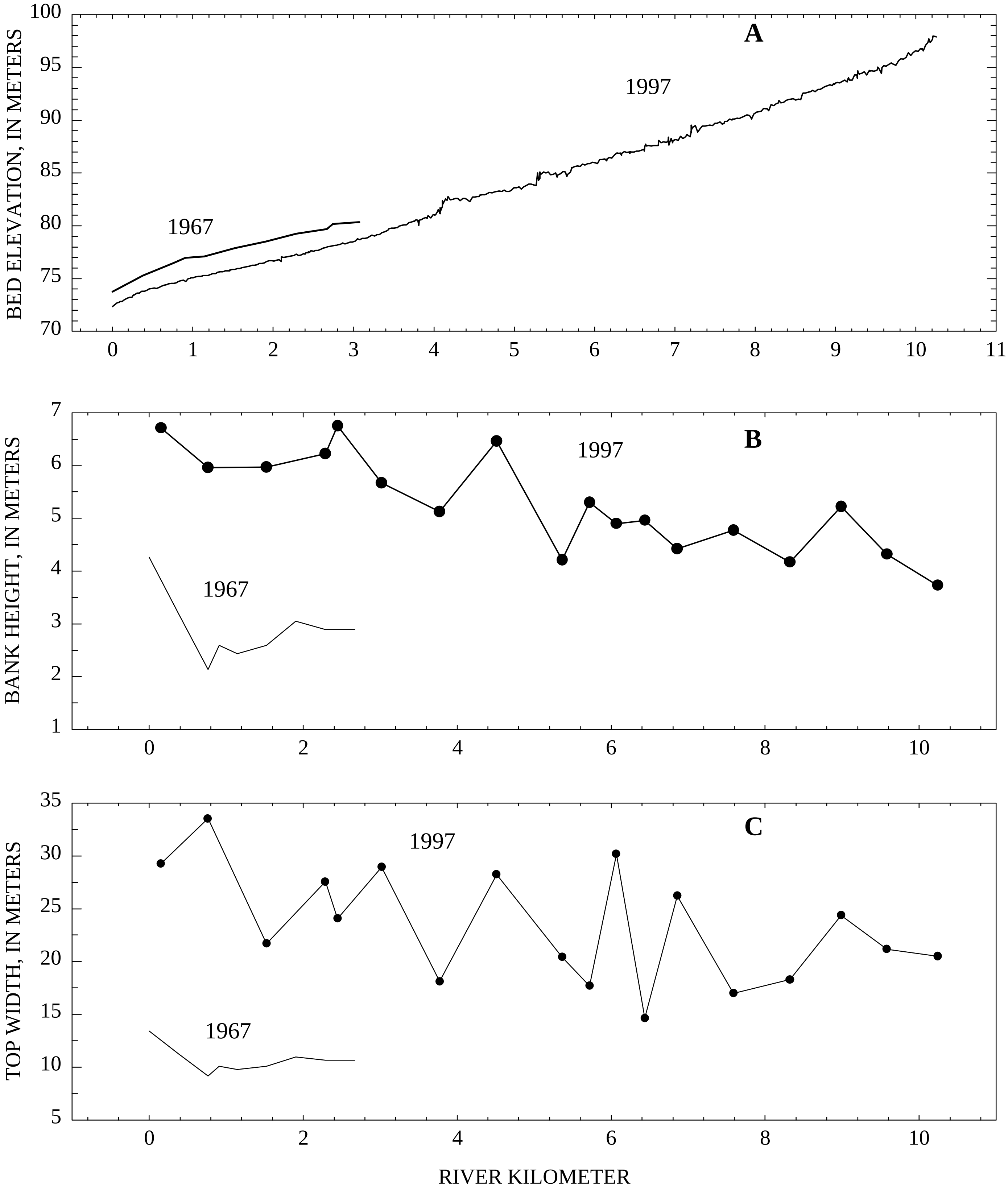


Figure 45--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Duncan Creek.

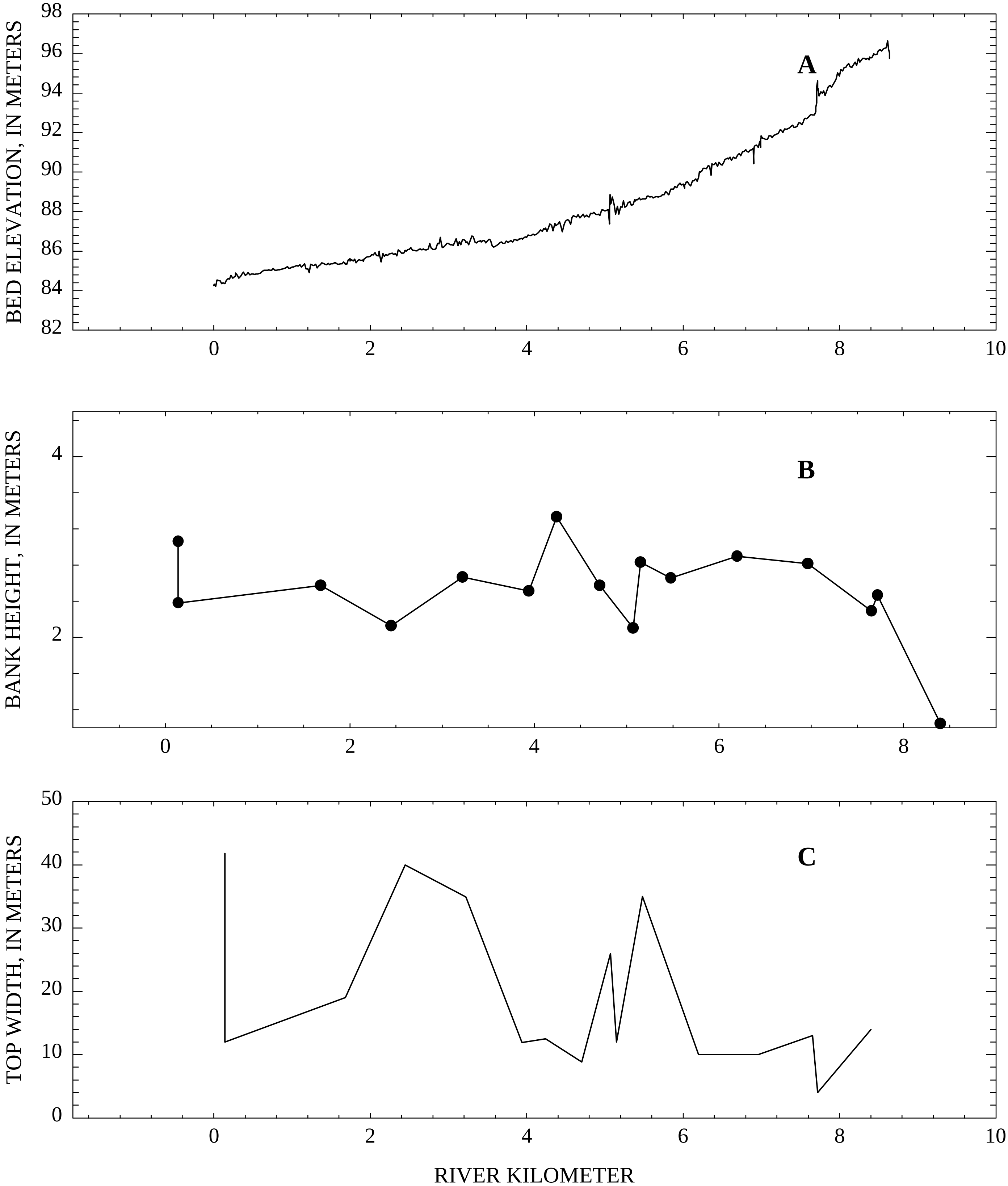


Figure 46--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Fair Creek.

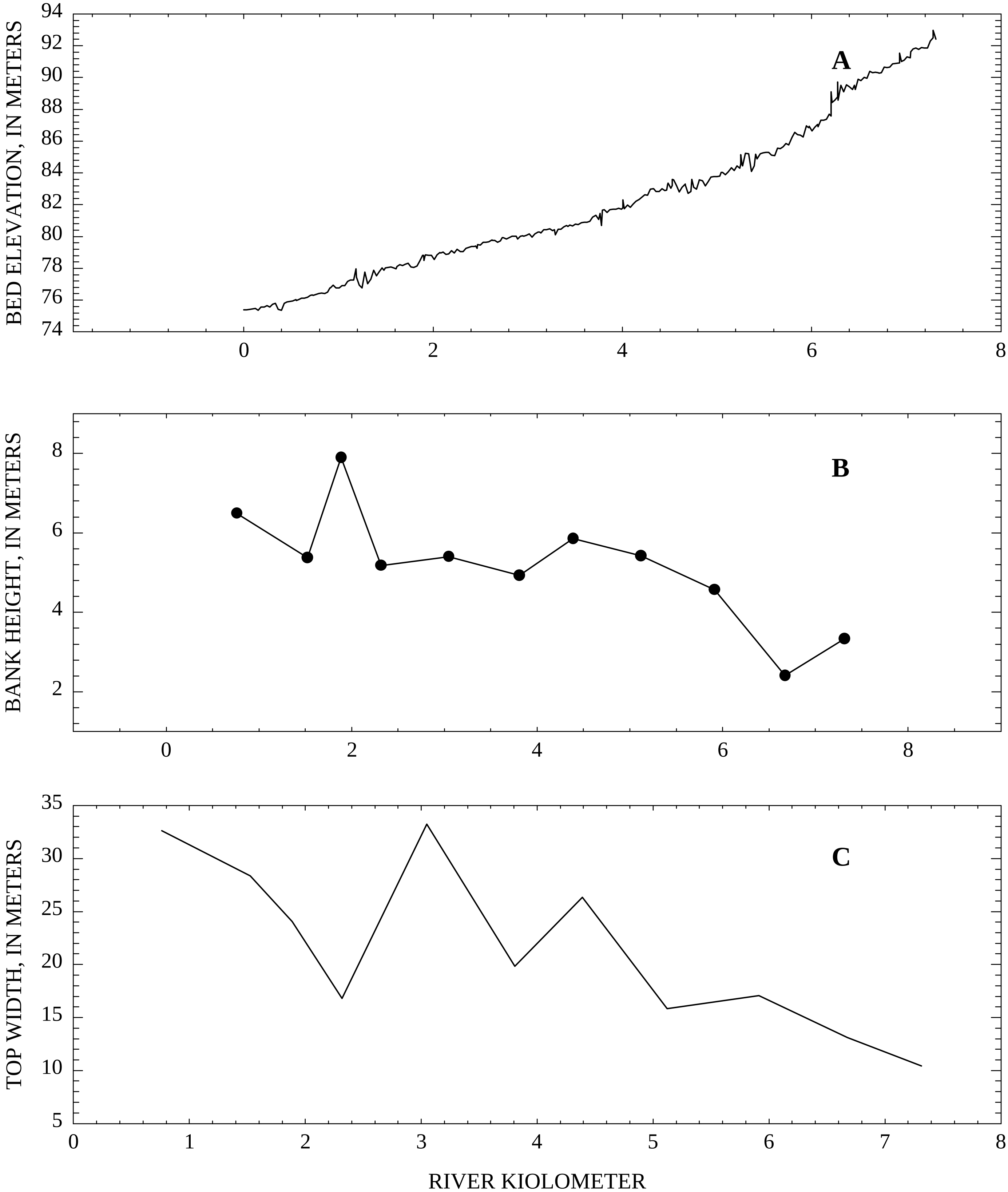


Figure 47--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Huffman Creek.

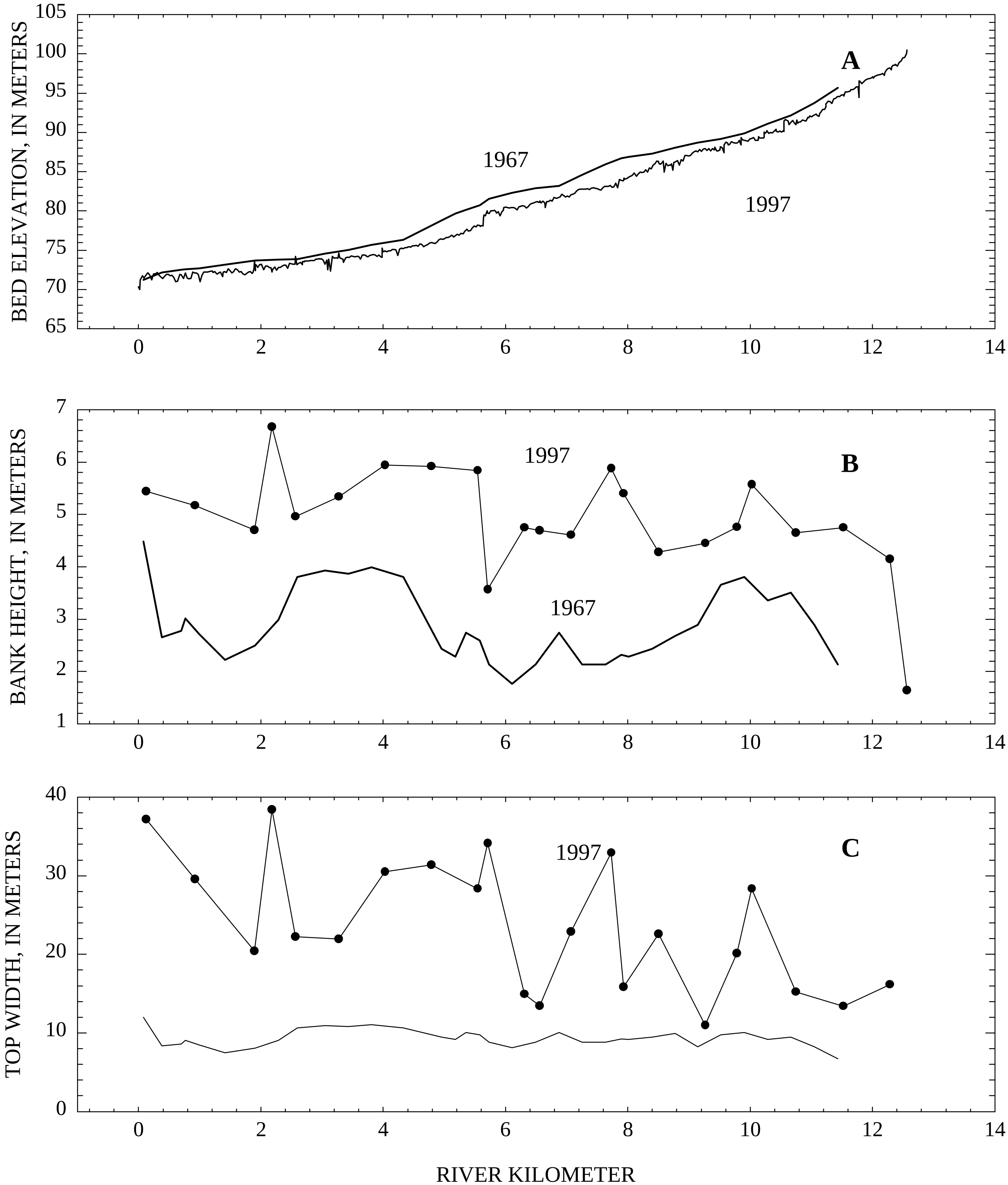


Figure 48--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Hurricane Creek.

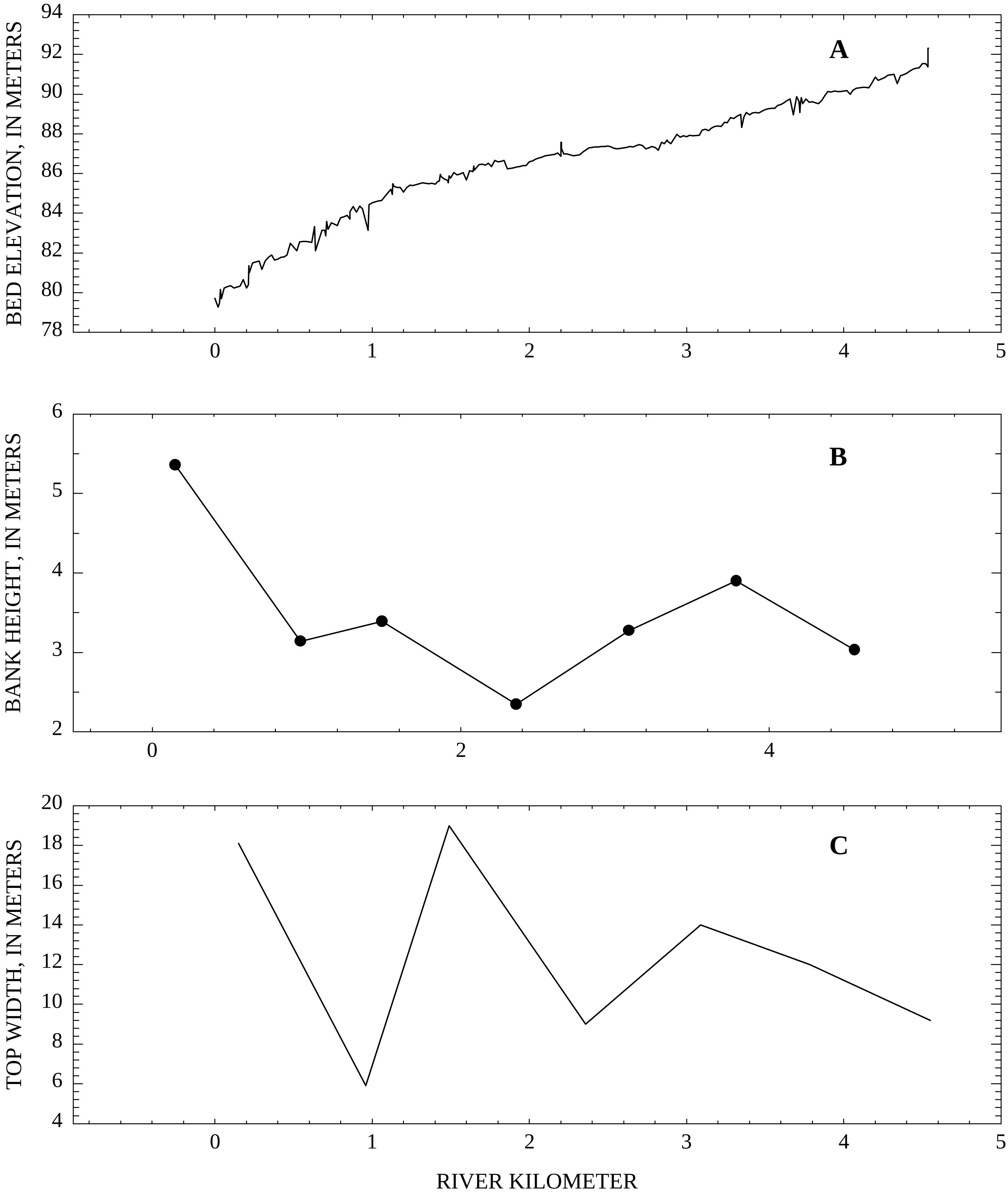


Figure 49--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Johnson Creek.

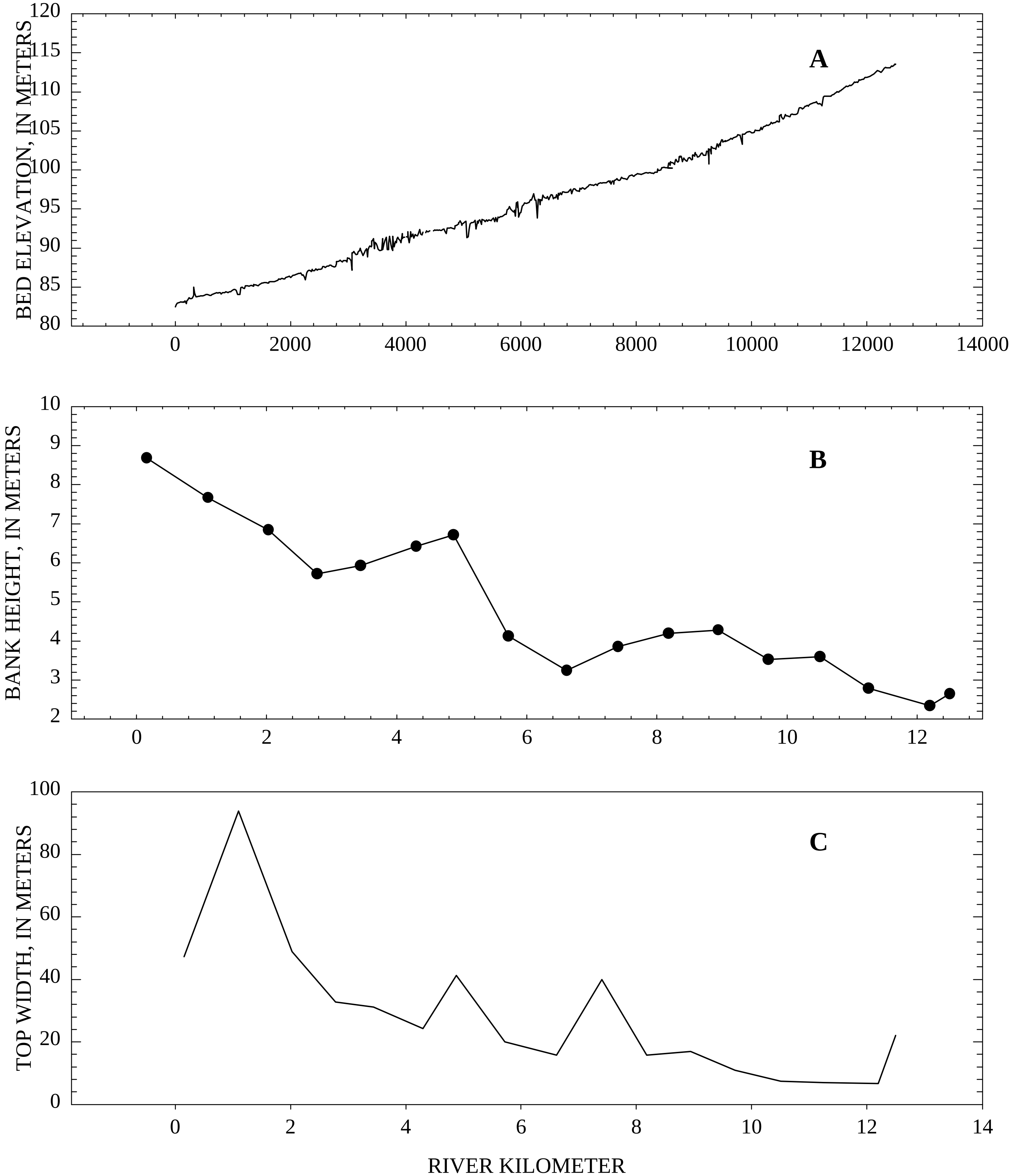


Figure 50--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Little Topashaw Creek.

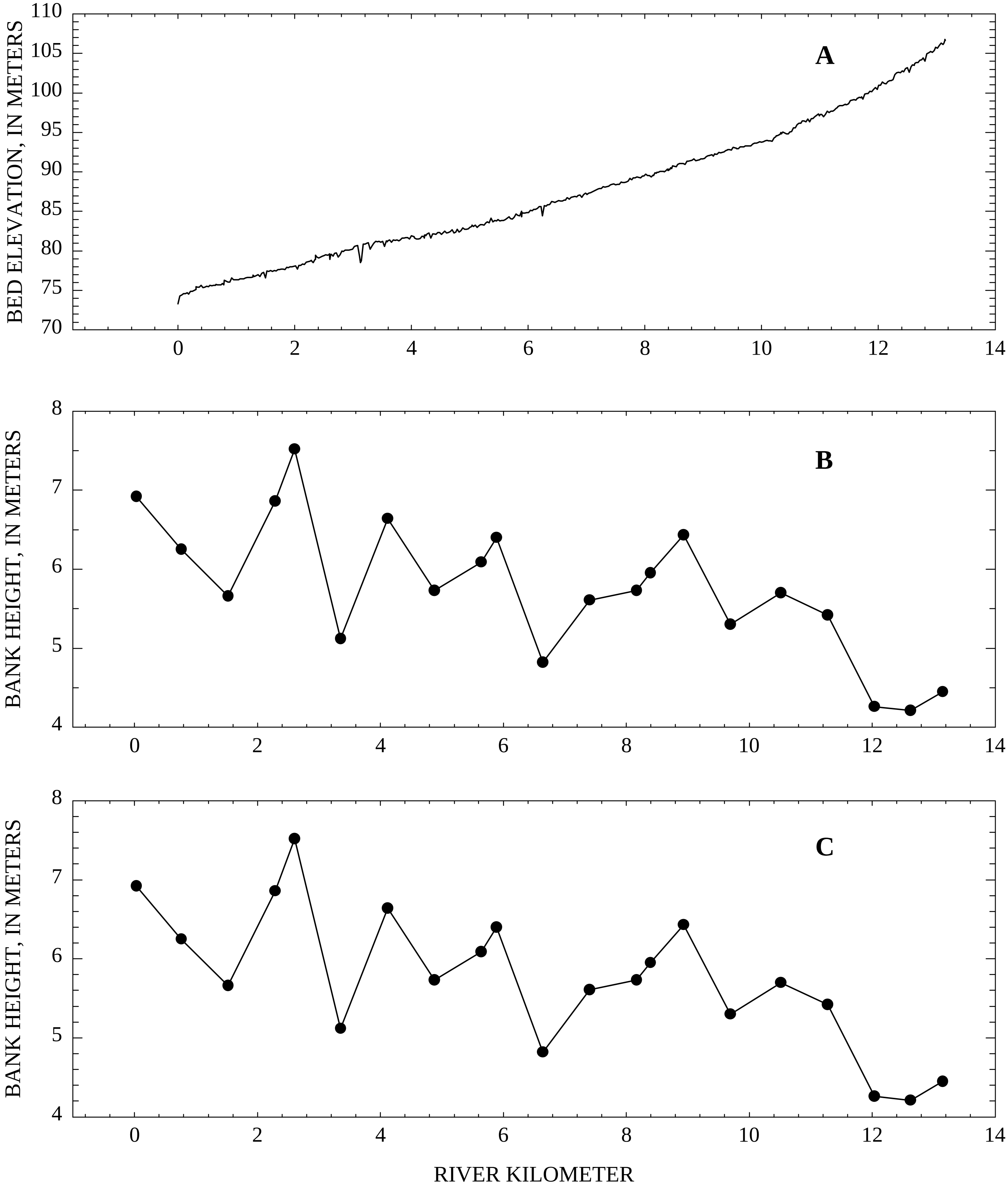


Figure 51--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Meridian Creek.

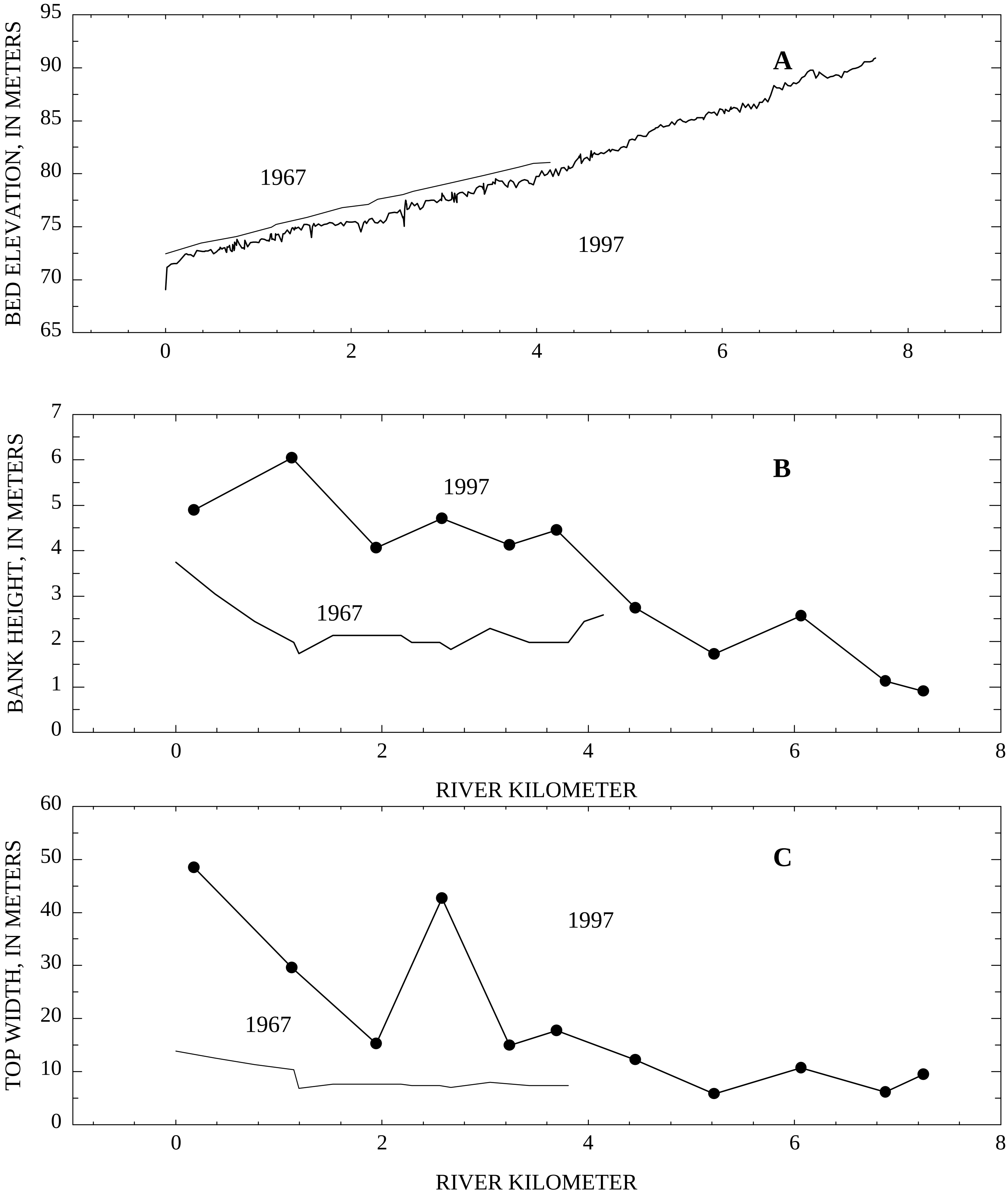


Figure 52--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Miles Creek.

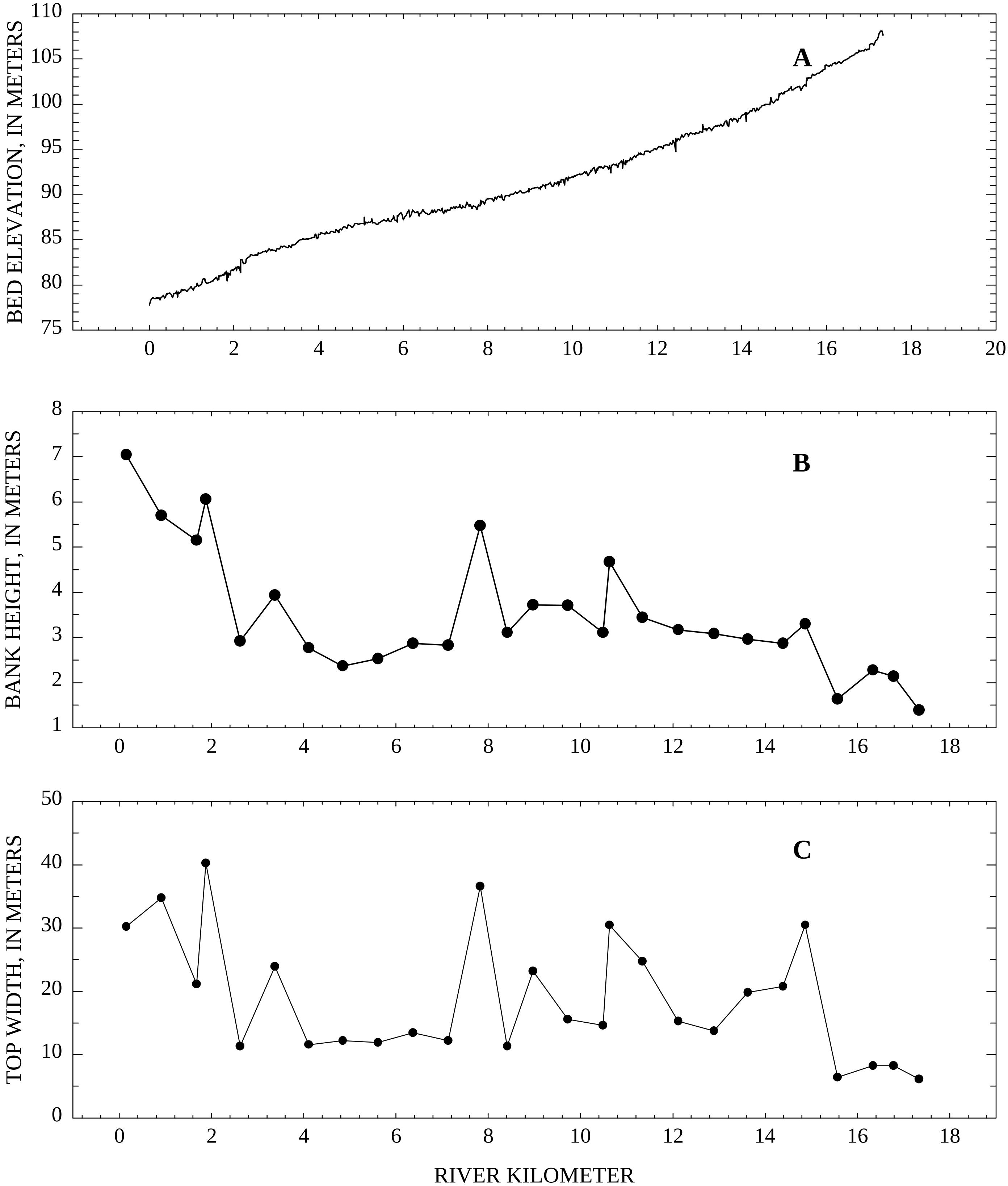


Figure 53--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Mud Creek.

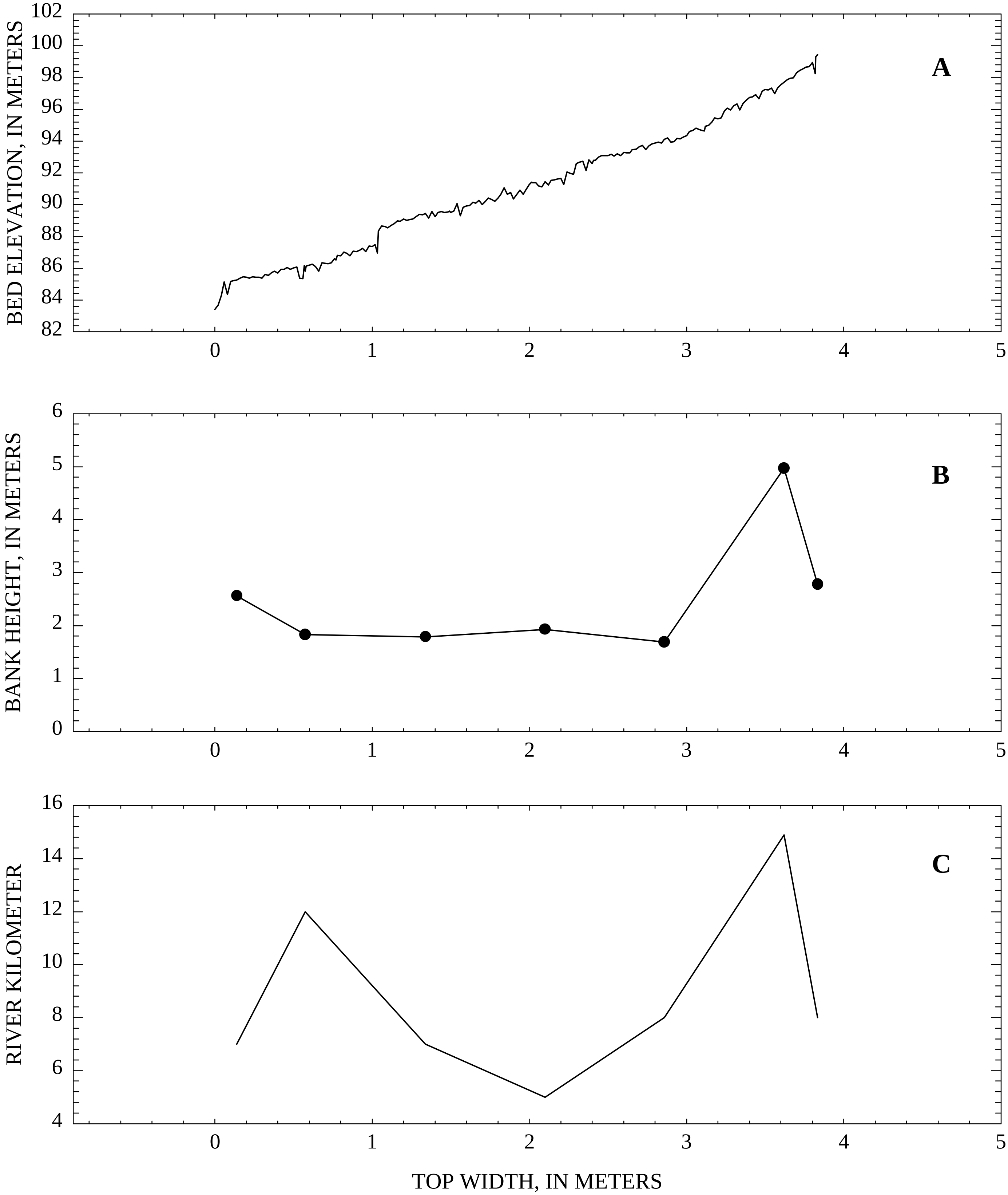


Figure 54--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Naron Creek.

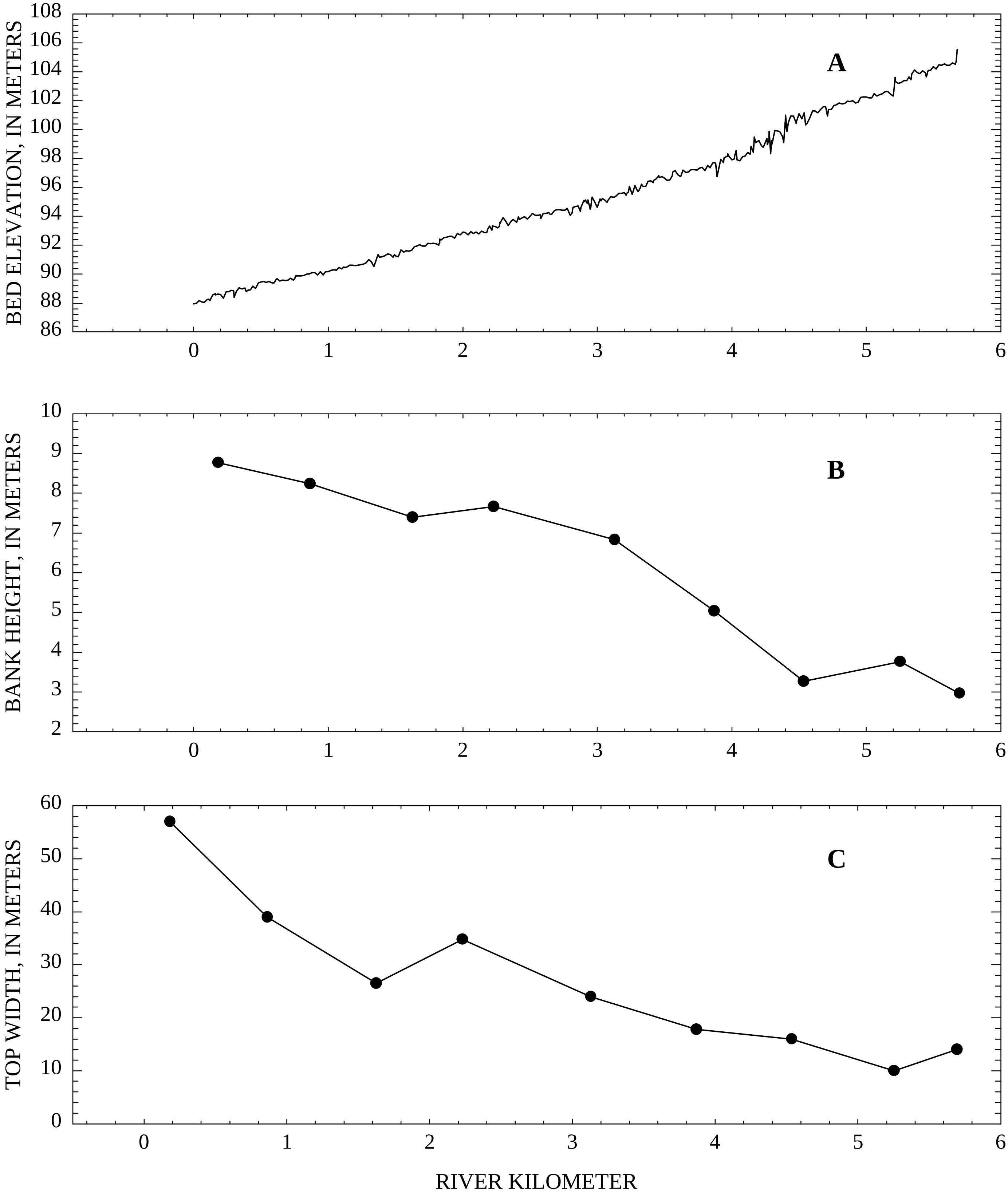


Figure 55--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for North Topashaw Creek.

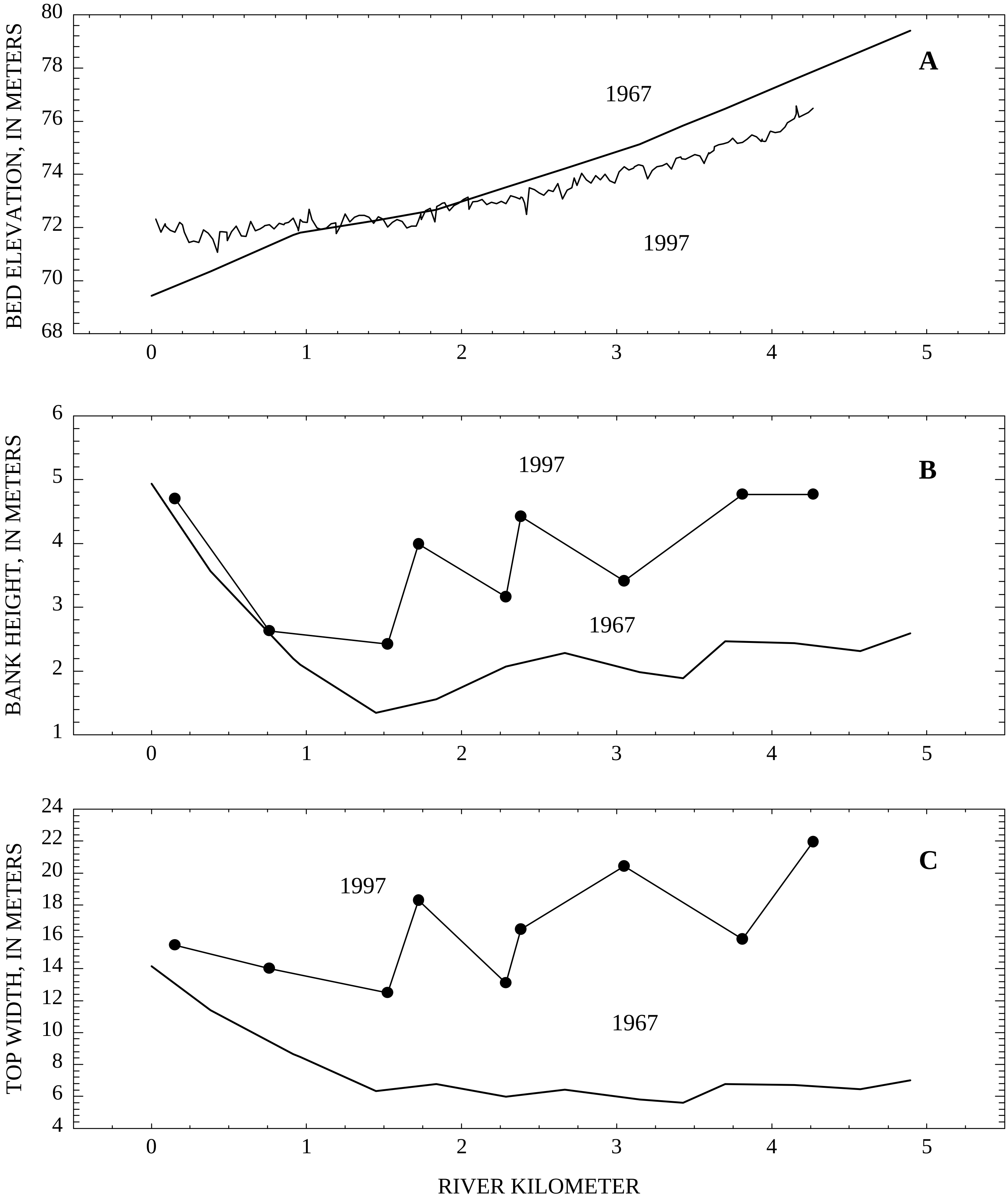


Figure 56--Longitudinal variation in thalweg profile (A), maximum bank height (B), and channel top width (C) for Splunge Creek.

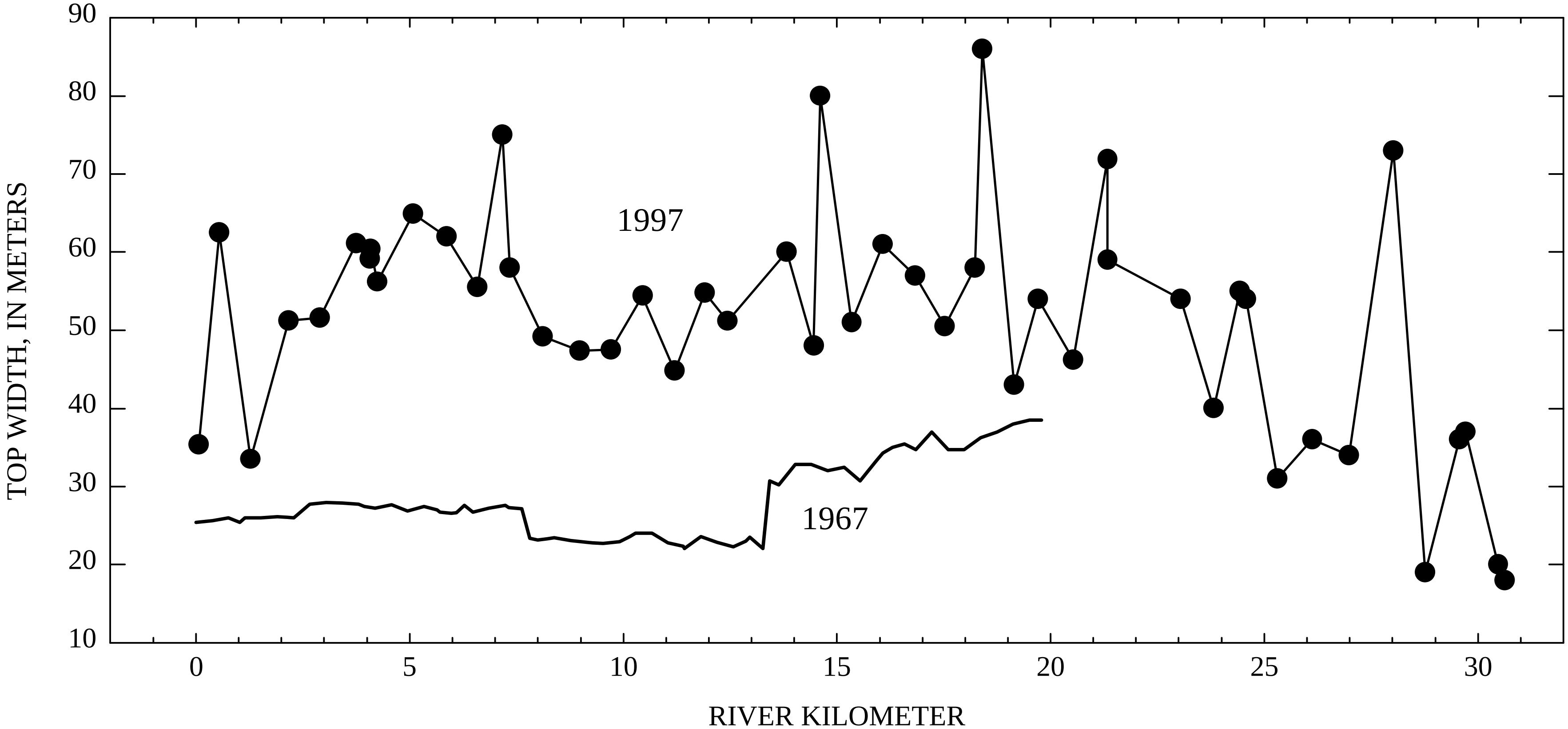


Figure 57--Changes in top width between 1967 and 1997 along Topashaw Creek.

Table 21--Summary of channel conditions and dominant bed and bank processes for studied reaches.

ARS Stream Name	CoE Stream Name	Sub-basin	Reach (rkm)	Stage	Bed Process	Bank Stability	Average of Maximum Bank Heights (m)
Anderson	Anderson	Duncan	0.0-2.6	3	Degradation	Stable	3.6
Bear	Bear	Topashaw	0.0-3.5	5	Aggradation	Unstable	8.4
			3.5-8.3	4	Degradation	Unstable	6.8
			8.3-8.7	3	Degradation	Transition[1]	5.5
			8.7-9.3	3	Degradation	Stable	3.7
			9.3-15.0	6 to 3	Transition	Stable	3.9
Bear T 1	B-1	Bear	0.0-0.2	4	Degradation	Unstable	-
			0.2-1.7	3	Degradation	Transition	2.8
Bear T 2	B-2	Bear	0.0-0.7	4	Degradation	Unstable	6.7
			0.7-1.8	3	Degradation	Transition	4.6
Bear T 3	B-3	Bear	0.0-1.4	3	Degradation	Transition	3.5
Bear T 4	B-4	Bear	0.0-1.8	3	Degradation	Transition	3.9
Big	Big	Yalobusha	0.0-1.9	6	Aggradation	Stable	4.9
			1.9-3.3	5	Aggradation	Transition	4.4
			3.3-6.3	5	Aggradation	Unstable	5.9
			6.3-9.3	4	Degradation	Unstable	6.6
			9.3-10.8	4	Degradation	Transition	4.9
			10.8-15.7	6 to 3	Transition	Stable	4.0
Buck	Buck	Topashaw	0.0-1.5	4	Degradation	Unstable	7.7
			1.5-3.0	3	Degradation	Transition	5.4
			3.0-13.5	6 to 3	Transition	Stable	3.3
Bull	Bull	Yalobusha	0.0-2.0	4	Degradation	Unstable	5.0
			2.0-2.5	3	Degradation	Transition	4.0
			2.5-4.0	6	Stable	Stable	1.6
Bull T 1	BC1	Bull	0.0-0.3	3	Degradation	Transition	2.9
Cane(Cook)		Yalobusha	0.0-7.3	5	Aggradation	Unstable	7.3
			7.3-11.8	4	Degradation	Unstable	6.5
			11.8-12.5	3	Degradation	Transition	4.7
			12.5-15.5	3	Transition	Stable	3.6
Dry	Dry (Reach 2)	Cane (Cook)	0.0-0.9	4	Degradation	Unstable	5.4
			0.9-3.2	3	Degradation	Stable	2.6

[1] in reaches with bends, outside bend is generally unstable and inside bend is generally stable.

ARS Stream Name	CoE Stream Name	Sub-basin	Reach (rkm)	Stage	Bed Process	Bank Stability	Average of Maximum Bank Heights (m)
			3.2-4.2	6 to 3	Transition	Stable	3.0
Dry	Dry	L. Topashaw	0.0-3.5	4	Degradation	Unstable	5.8
			3.5-4.2	3	Degradation	Transtion	4.9
			4.2-5.3	3	Transition	Stable	4.6
Duncan	Duncan	Yalobusha	0.0-4.1	5	Aggradation	Unstable	6.1
			4.1-9.0	4	Degradation	Unstable	4.9
			9.0-10.5	3	Degradation	Transition	4.0
Fair	Fair	Yalobusha	0.0-8.4	2 to 3	Transition	Stable	2.5
Fair T 1	Fair Trib 1	Fair	0.0-1.0	2	Transition	Stable	1.7
Gordon	Gordon	Mud	0.0-2.1	3	Degradation	Stable	2.9
			2.1-6.0	6 to 3	Transition	Stable	1.7
Huffman	Huffman	Hurricane	0.0-4.0	5	Aggradation	Unstable	5.9
			4.0-5.5	4	Degradation	Unstable	5.6
			5.5-6.2	3	Degradation	Transition	4.6
			6.2-7.3	6 to 3	Transition	Stable	2.9
Huffman T 1	Creek #1	Huffman	0.0-1.8	4	Degradation	Transition	4.1
			1.8-2.2	3	Degradation	Stable	4.2
Hurricane	Hurricane 2	Yalobusha	0.0-1.9	6	Aggradation	Stable	5.1
			1.9-7.8	5	Aggradation	Transition	5.3
			7.8-10.6	4	Degradation	Unstable	4.9
			10.6-12.6	3	Degradation	Transition	3.8
Hurricane	Hurricane 2	Walnut	0.0-0.4	4	Degradation	Unstable	5.0
			0.4-3.6	3	Degradation	Transition	3.5
			3.6-4.2	6 to 3	Transition	Stable	2.7
Johnson	Johnson	Yalobusha	0.0-0.9	4	Degradation	Unstable	5.4
			0.9-4.5	3	Degradation	Stable	3.2
Johnson T 1	J-4	Johnson	0.0-1.6	3	Degradation	Transition	2.2
Lick		Mud	0.0-6.8	3	Degradation	Stable	1.7
			6.8-7.6	6 to 3	Transition	Stable	1.4
L.Topashaw	LT-3	Topashaw	0.0-1.9	5	Aggradation	Unstable	8.2
			1.9-5.6	4	Degradation	Unstable	6.3
			5.6-12.4	3	Degradation	Transition	3.5
L. Topashaw T 1	LT-1	L. Topashaw	0.0-2.0	5 to6	Aggradation	Stable	4.3

[1] in reaches with bends, outside bend is generally unstable and inside bend is generally stable.

ARS Stream Name	CoE Stream Name	Sub-basin	Reach (rkm)	Stage	Bed Process	Bank Stability	Average of Maximum Bank Heights (m)
			2.0-3.0	5 to 4	Transition	Transition	4.0
L. Topashaw T 2	LT-2	L.Topashaw	0.0-1.5	3	Degradation	Transition	3.6
Meridian	Meridian	Yalobusha	0.0-4.8	6	Aggradation	Transition	6.4
			4.8-7.0	5	Aggradation	Unstable	5.8
			7.0-11.8	3	Degradation	Transition	5.7
			11.8-13.1	6	Transition	Stable	4.3
Meridian T 1	M-2	Meridian	0.0-1.9	3	Degradation	Transition	5.2
			1.9-2.5	3	Degradation	Stable	4.0
Meridian T 2	M-1	Meridian	0.0-0.2	3	Degradation	Transition	6.4
			0.2-1.2	3	Degradation	Stable	2.2
Miles	Miles	Yalobusha	0.0-2.6	3	Degradation	Transition	4.9
			2.6-7.3	6	Transition	Stable	2.7
Mud	Mud	Yalobusha	0.0-2.2	4	Degradation	Unstable	6.0
			2.2-15.6	3	Degradation	Transition	3.3
			15.6-17.3	6 to 3	Transition	Stable	1.9
Mud T 1	MC2	Mud	0.0-0.9	3	Degradation	Stable	1.9
Mud T 3	MC4	Mud	0.0-1.0	3	Degradation	Stable	2.0
Naron #1	Naron #1	Yalobusha	0.0-0.3	4	Degradation	Unstable	4.3
			0.3-6.3	6	Stable	Stable	2.1
Naron #2	Naron #2	Johnson	0.0-0.2	4	Degradation	Unstable	4.2
			0.2-2.9	3	Degradation	Transition	1.8
			2.9-3.7	6	Stable	Stable	1.7
N. Topashaw	Topashaw Trib 5-A	Topashaw	0.0-1.4	5	Aggradation	Unstable	8.5
			1.4-4.1	4	Degradation	Unstable	6.7
			4.1-5.7	3	Degradation	Stable	3.3
N. Topashaw T 1	T-3	N. Topashaw	0.0-0.2	4	Degradation	Unstable	6.7
			0.2-0.9	3	Degradation	Stable	2.1
N. Topashaw T 2	T-4	N. Topashaw	0.0-1.4	4	Degradation	Unstable	6.3
			1.4-1.5	3	Degradation	Transition	4.3
Splunge	Splunge	Yalobusha	0.0-2.0	6	Aggradation	Stable	3.4
			2.0-3.9	5	Aggradation	Transition	3.9
			3.9-4.2	4	Degradation	Unstable	4.8
			4.2-4.3	3	Degradation	Transition	-

[1] in reaches with bends, outside bend is generally unstable and inside bend is generally stable.

ARS Stream Name	CoE Stream Name	Sub-basin	Reach (rkm)	Stage	Bed Process	Bank Stability	Average of Maximum Bank Heights (m)
Topashaw	Topashaw	Yalobusha	0.0-8.0	6	Stable	Stable	7.0
			8.0-21.0	5	Aggradation	Unstable	9.2
			21.0-30.0	4	Degradation	Unstable	7.8
			30.0-30.6	3	Degradation	Transition	5.1
Topasahw T 1	T-1	Topasahw	0.0-2.3	4	Degradation	Unstable	7.6
			2.3-3.6	3	Degradation	Transition	4.0
Topashaw T 2	T-2	Topashaw	0.0-1.1	4	Degradation	Unstable	6.4
			1.1-3.0	3	Degradation	Transition	3.7
Topasahw T 3	T-6	Topasahw	0.0-0.2	4	Degradation	Unstable	7.4
			0.2-0.8	3	Degradation	Transition	4.1
Topashaw T 4	T-7	Topashaw	0.0-0.8	4	Degradation	Unstable	6.4
			0.8-2.1	3	Degradation	Stable	2.7
Twin	Twin	Huffman	0.0-1.2	4	Degradation	Transition	3.7
			1.2-2.2	3	Degradation	Stable	2.4
Walnut	Walnut	Cane (Cook)	0.0-2.6	4	Degradation	Unstable	5.6
			2.6-4.7	3	Degradation	Transition	3.6
			4.7-6.0	6 to 3	Transition	Stable	2.2
Walnut T 1	W-1	Walnut	0.0-0.3	3	Degradation	Transition	3.0
			0.3-1.2	6	Stable	Stable	1.4
Yalobusha	Yalobusha	Yalobusha	-7.4-0.0	6	Lake	Stable	2.1
			0.0-9.2	6	Aggradation	Stable	6.4
			9.2-14.3	5	Aggradation	Unstable	10.8
			14.3-17.0	6	Aggradation	Stable	7.6
			17.0-26.0	5	Aggradation	Transition	9.6
			26.0-29.5	4	Degradation	Unstable	8.6
			29.5-44.0	3	Degradation	Transition	3.2
			44.0-54.0	1	Stable	Stable	-
Yalobusha T 1	YR-2	Yalobusha	0.0-3.6	3	Degradation	Transition	3.9
			3.6-4.8	6	Stable	Stable	2.3
Yalobusha T 2	YR-1	Yalobusha	0.0-4.4	3	Degradation	Transition	2.1

[1] in reaches with bends, outside bend is generally unstable and inside bend is generally stable.

relations between suspended-sediment concentration and flow discharge are likely to contain considerable scatter.

In addition to Plates 1 and 2, which provide systemwide information regarding study sites, dominant bed-material size, and stage of channel evolution, channel conditions along the studied streams are summarized in a series of figures and tables. These data are collated such that they provide readily accessible information regarding thalweg profiles (Figures 39A-56A), maximum bank heights (channel depths; Figures 39B-56B), and top widths (Figures 39C-56C). Figures 57 and 58 provide a means of comparing changes in channel top-widths for the Yalobusha River and Topashaw Creek. Through documentation of channel conditions, stages of channel evolution and analysis of channel surveys throughout the Yalobusha River System, a summary table of present stability conditions is provided (Table 21). Dominant channel processes are separated into bank and bed processes. For convenience, stream names used by the ARS and by the Corps of Engineers are also listed. Much of the data used to develop Table 21 came from data collected during the field reconnaissance phase of the study. These raw data are provided in Table 3.

Presently engineering solutions to these problems employ combinations of small reservoirs, grade-control structures, and bank protection. In some cases, re-channelization of aggraded downstream reaches has also been performed. Protection against upstream erosion and downstream flooding is often diametrically opposed because methods to increase downstream channel capacity can result in rejuvenation of already oversized reaches upstream. To reduce the potential for flooding in the lower Yalobusha River and Topashaw Creek, downstream channels must be able to convey more water and sediment than previous. This must be accomplished without causing a drastic change in the flow energy-sediment supply balance at the transition zone. In some cases, degradation has been induced downstream from erosion-control structures, thereby destabilizing channel banks (Simon and Darby, 1997). With bank material comprising as much as 92% of the material eroded from channels in the river system, this becomes a serious consideration in terms of maintaining downstream channel capacity.

Mitigation of downstream flooding and upstream erosion problems will require a full consideration of boundary conditions and dominant processes throughout the entire fluvial system. Processes of erosion and sediment supply by mass wasting and fluvial deposition must be balanced relative to the distribution of available stream power and flow energy. Because upstream channels cannot easily entrain material from the channel bed, sediment-transport rates are probably considerably less than capacity for most if not all flows. Strategies for stable slopes and hydraulic conditions must account for this imbalance between available flow energy and the limited sediment availability from the channel bed. Such an approach may yield substantial benefits in terms of channel recovery and habitat quality. A transition between the channelized reach and the meandering reach downstream could provide opportunity for floodplain habitat rehabilitation.

ACKNOWLEDGMENTS

The author would like to express his sincere gratitude to all those colleagues who conducted and assisted with the collection, compilation, and analysis of the data used in this report. Particular thanks are extended to those who spent long hours with me, day after day, walking channels with noxious reptiles during the field-evaluation phase of the study. From the National Sedimentation Laboratory: Bernard Booth, Jasper Hardison, Keith Parker, and Tony Rohs; from Waterways Experiment Station: David Biedenharn and Lisa Hubbard. I would also like to thank Jimmy Gray and his staff, U.S. Army Corps of Engineers, for providing timely processing of bed- and bank-material samples, and K. Van Wilson, U.S. Geological Survey for supplying hydrologic and minimum-stage data. Brian Bell, Andrea Curini, and Lance Yarbrough of the National Sedimentation Laboratory are recognized for their assistance in data analysis and preparation of graphs. Neil Jones, an undergraduate student from the University of Nottingham collated aerial photographs and sketched historical planforms. Finally, I would like to thank John Smith, U.S. Army Corps of Engineers, for providing straightforward leadership in his overseeing of our work. This study could not have been completed without the help of these people.

REFERENCES

Carson, M.A., 1971, Application of the concept of threshold slopes to the Laramie Mountains, Wyoming. Trans. Of the Institute of British Geographers, Special Publication 3.

Collison, A.J.C., and Anderson, M.G., 1996, Using a combined slope hydrology/stability model to identify suitable conditions for landslide prevention by vegetation in the humid tropics. Earth Surface Processes and Landforms, v. 21, no. 8, 737-748.

Culmann, C., 1866, Graphische Statik (Zurich).

Curini, A., 1998, Analisi dei processi di erosione di sponda nei corsi d'acqua, Universita degli Studi di Firenze, Dipartimento di Scienze della Terra, 147.

Elliott, J.G., 1979, Evolution of large arroyos, the Rio Puerco of New Mexico. Colorado State University, Fort Collins, Colorado, Master of Science thesis, 106 p.

Fredlund,, D.G., Morgenstern, N.R., and Widger, R.A., 1978, The shear strength of unsaturated soils. Canadian Geotechnical Journal, v. 15, 313-321.

Hanson, G.J., 1991, Development of a submerged jet index to characterize erosion resistance of soils in earthen spillways, Trans., ASAE, v. 34, no. 5, 2015-2020.

Lowe, E.N., 1910, Our waste lands: A preliminary study of erosion in Mississippi. Mississippi Geological Survey, Jackson, Mississippi.

Lutton, R.J., 1974, Use of loess for modeling rock mechanics. U.S. Army Corps of Engineers, Waterways Experiment Station Reports S-74-28, Vicksburg, Mississippi.

Mississippi Board of Development, 1940a, Report Yalobusha Swamp Land District No. 1, Calhoun County, Mississippi. W.P.A. Project No. 5483, Statewide Drainage Survey, Jackson, Mississippi.

Mississippi Board of Development, 1940b, Report Topasahw Swamp Land District, Calhoun County, Mississippi. W.P.A. Project No. 5483, Statewide Drainage Survey, Jackson, Mississippi.

Mississippi Board of Development, 1940c, Report Topasahw Drainage District No. 2, Chickasaw County, Mississippi. W.P.A. Project No. 5483, Statewide Drainage Survey, Jackson, Mississippi.

Mississippi State Planning Commission, 1936, Report on the Yazoo River Drainage Basin.

Newcome, R. Jr., and Bettandorff, J.M., 1973, Water for industrial development in Calhoun, Chickasaw, Choctaw, Grenada, Montgomery, Webster, and Yalobusha Counties, Mississippi. Mississippi Research and Development Center, 64 p.

Schumm, S.A., Harvey, M.D., and Watson, C.C., 1984, Incised Channels, Morphology, Dynamics, and Control. Water Resources Publications, Littleton, Colorado, 200 p.

Simon, A., and Curini, A., 1998, Pore pressure and bank stability: The influence of matric suction. In S. Abt (Editor), Hydraulic Engineering, '98, ASCE.

Simon, A., and Darby, S.E., 1997, Process-form interactions in unstable sand-bed channels: A numerical modeling approach. Geomorphology, v. 21, pp. 85-106.

Simon, A., and Hupp, C. R., 1986, Channel evolution in modified Tennessee channels. Proc. Fourth Federal Interagency Sedimentation Conference, Las Vegas, March 24-27, 1986, v. 2, p. 5-71 to 5-82.

Simon, A., 1989, A model of channel response in disturbed alluvial channels. Earth Surface Processes and Landforms, v. 14, pp. 11-26.

Simon, A., 1992, Energy, time, and channel evolution in catastrophically disturbed fluvial systems. Geomorphology, v. 5, 345-372.

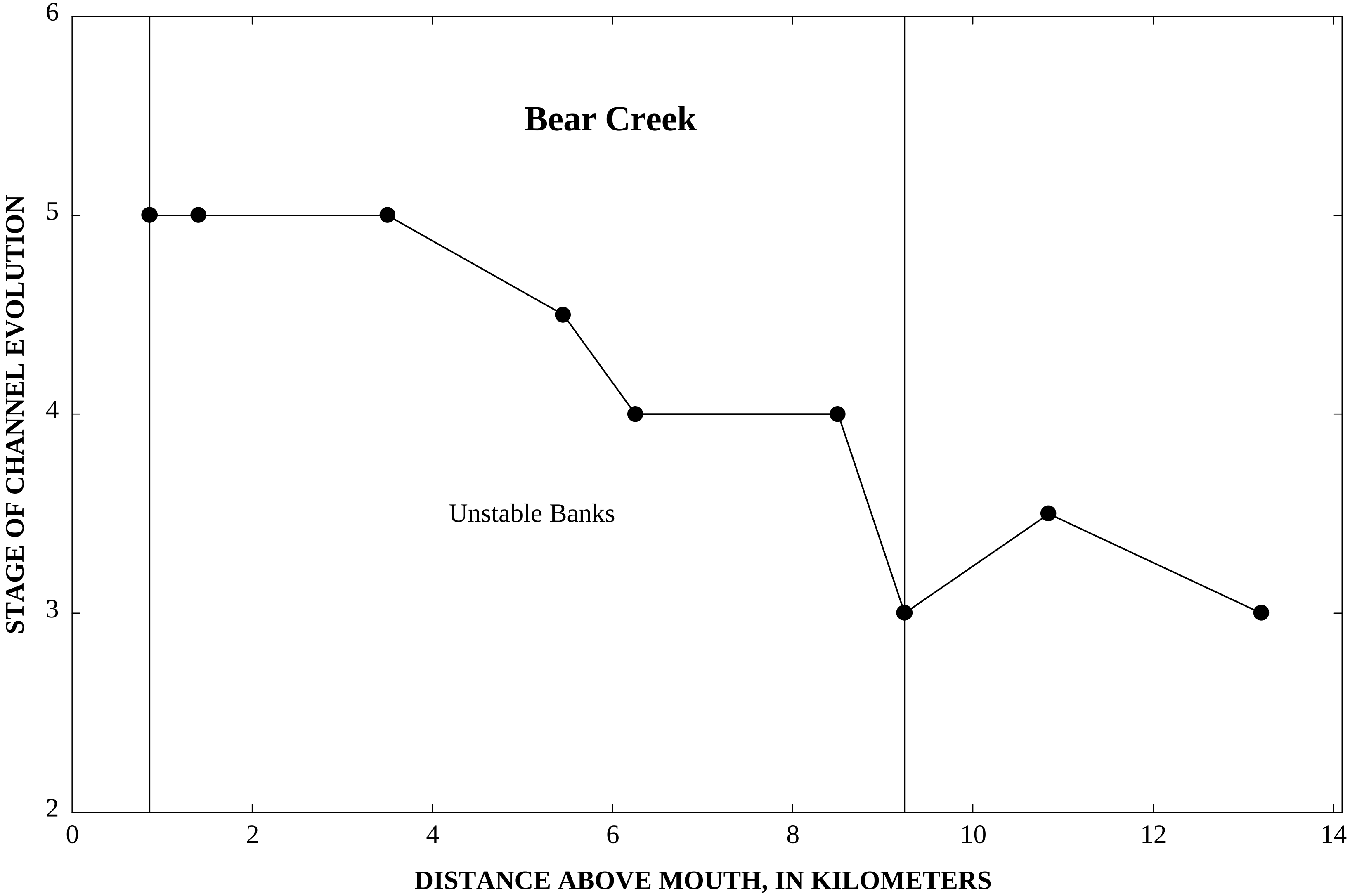
Simon, A., 1994, Gradation processes and channel evolution in modified West Tennessee streams, process, response, and form. U.S. Geological Survey Professional Paper 1470, 84 p.

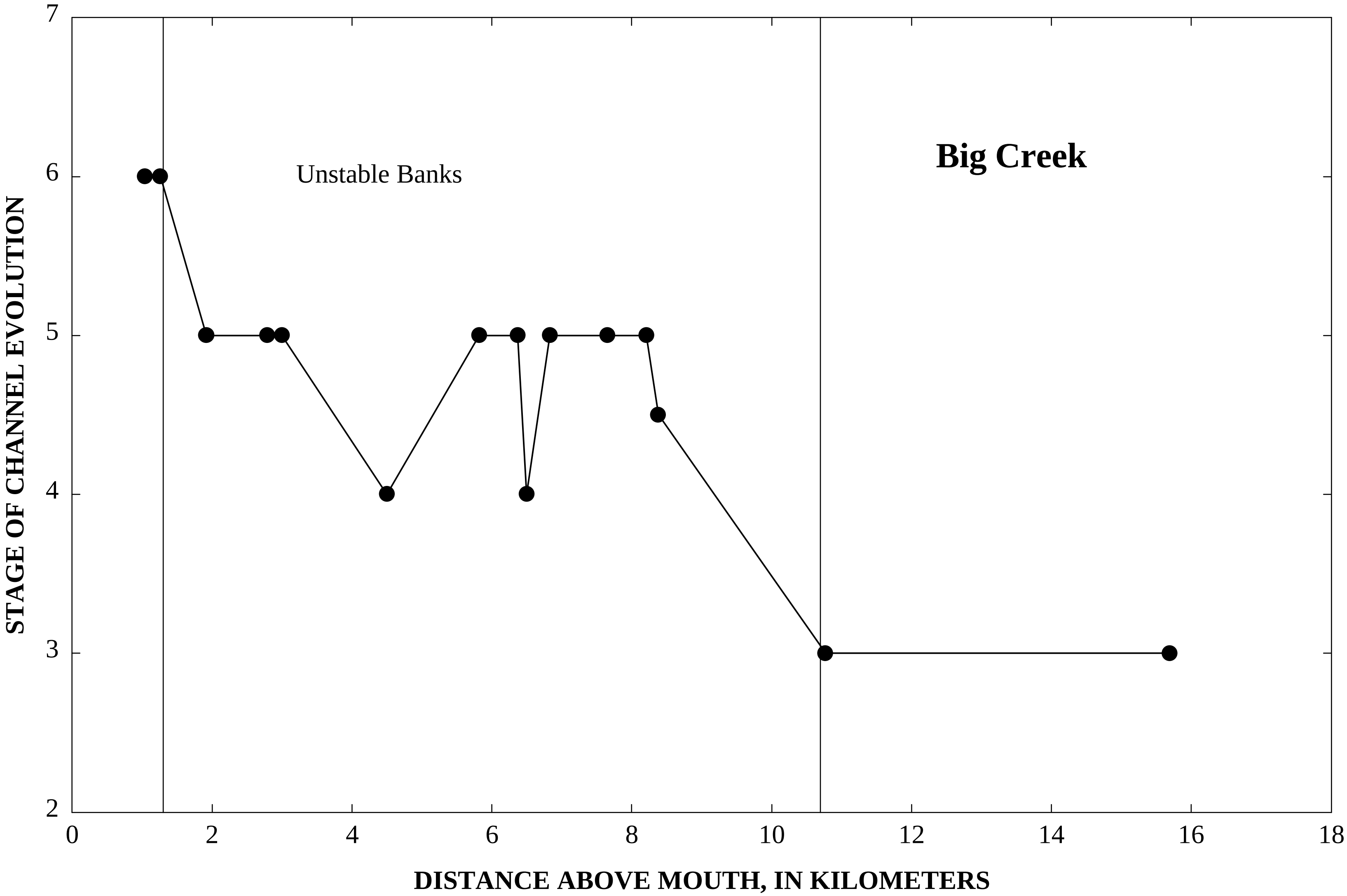
Thorne, C.R., 1990, Effects of vegetation of riverbank erosion and stability, in Thornes, J.B., (ed.) Vegetation and Erosion, Chichester, England, John Wiley and Sons, p. 125-144.

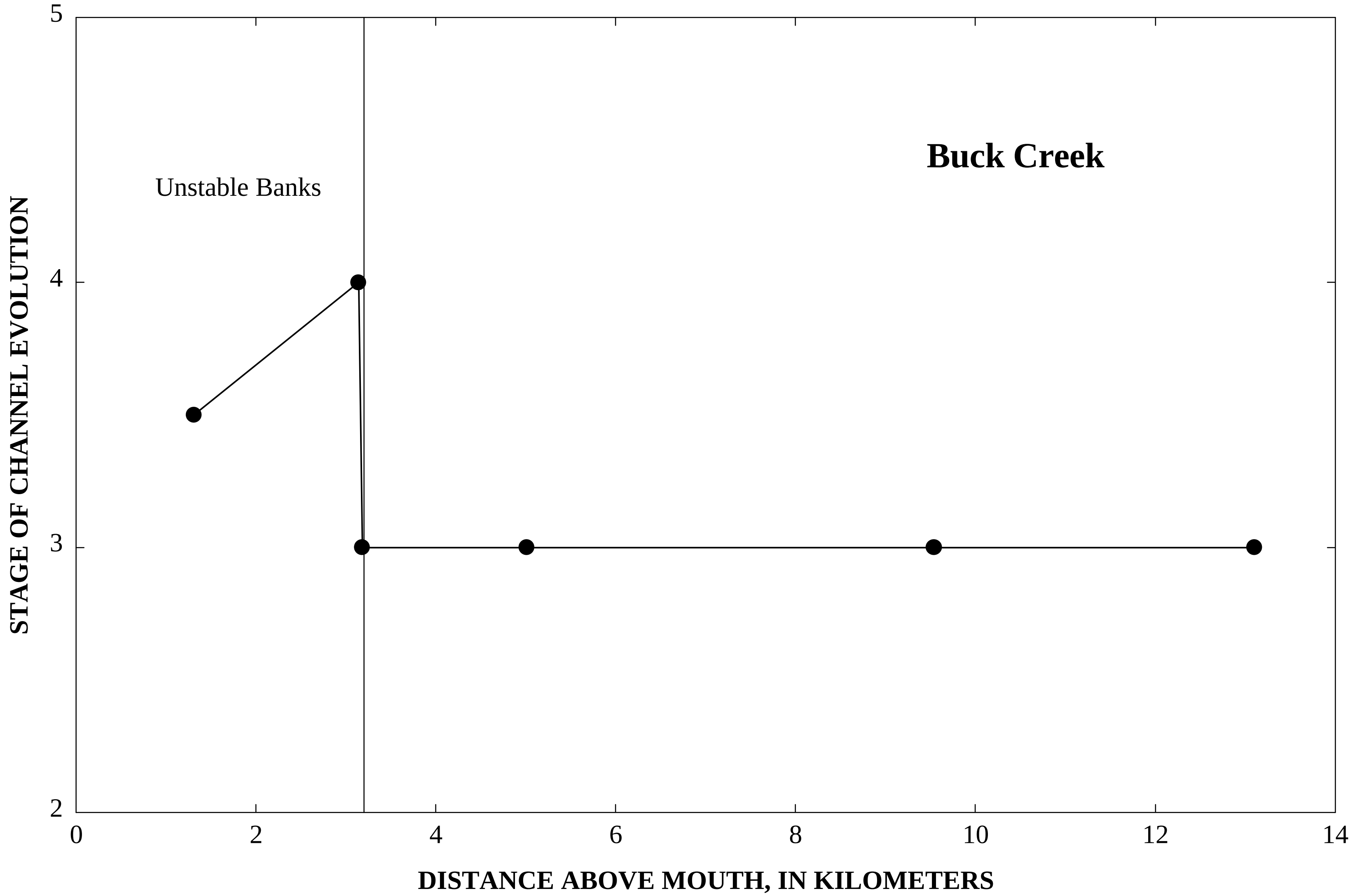
U.S. Army Corps of Engineers, 1993, Yazoo Basin Mississippi, Demonstration Erosion Control Project, Coldwater River Watershed, Supplement 1 to General Design Memorandum No. 54, Vicksburg District.

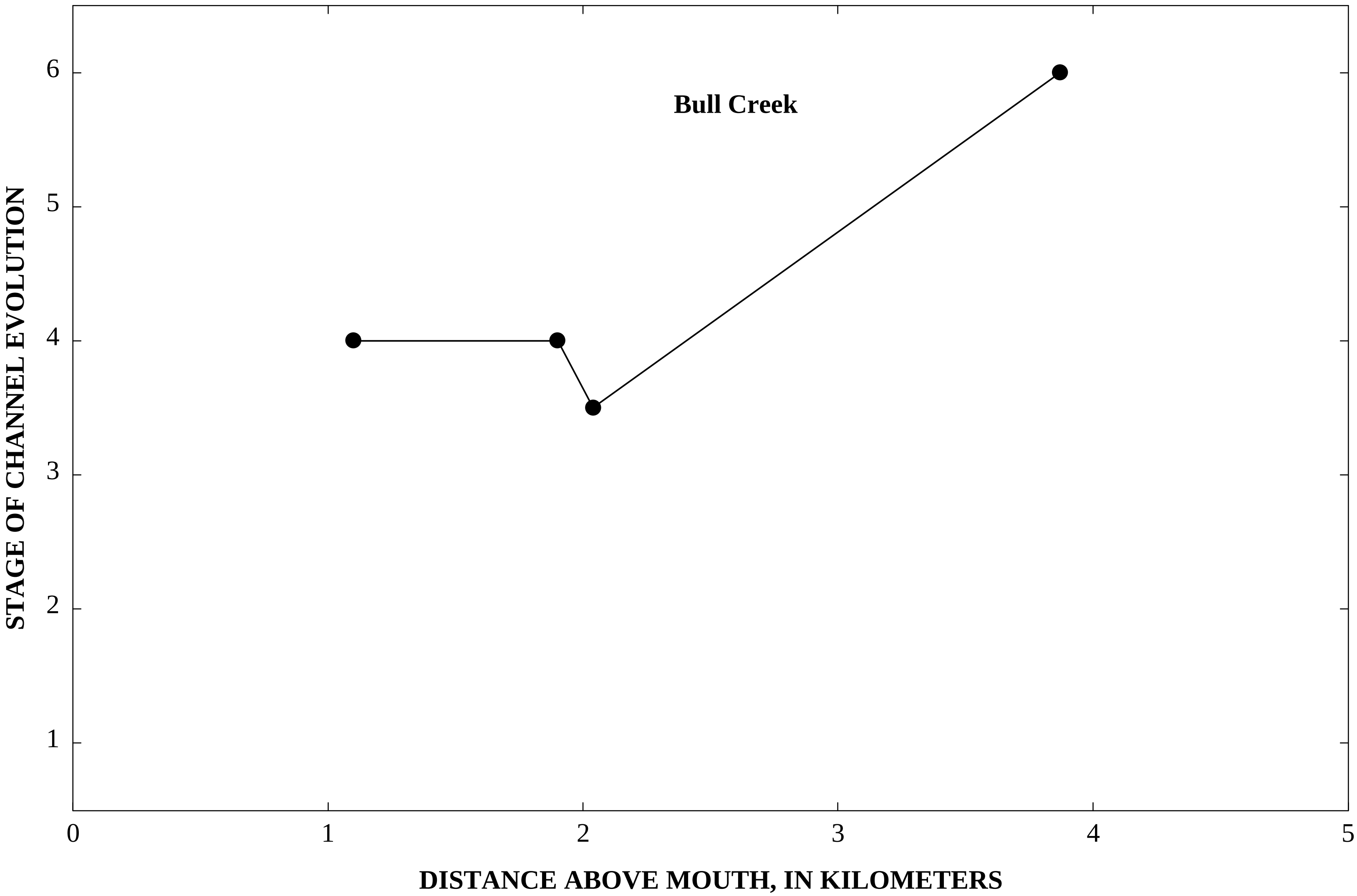
Vidal, H., 1969, The principle of reinforced earth. Highway Research Record, v. 282, p. 1-16.

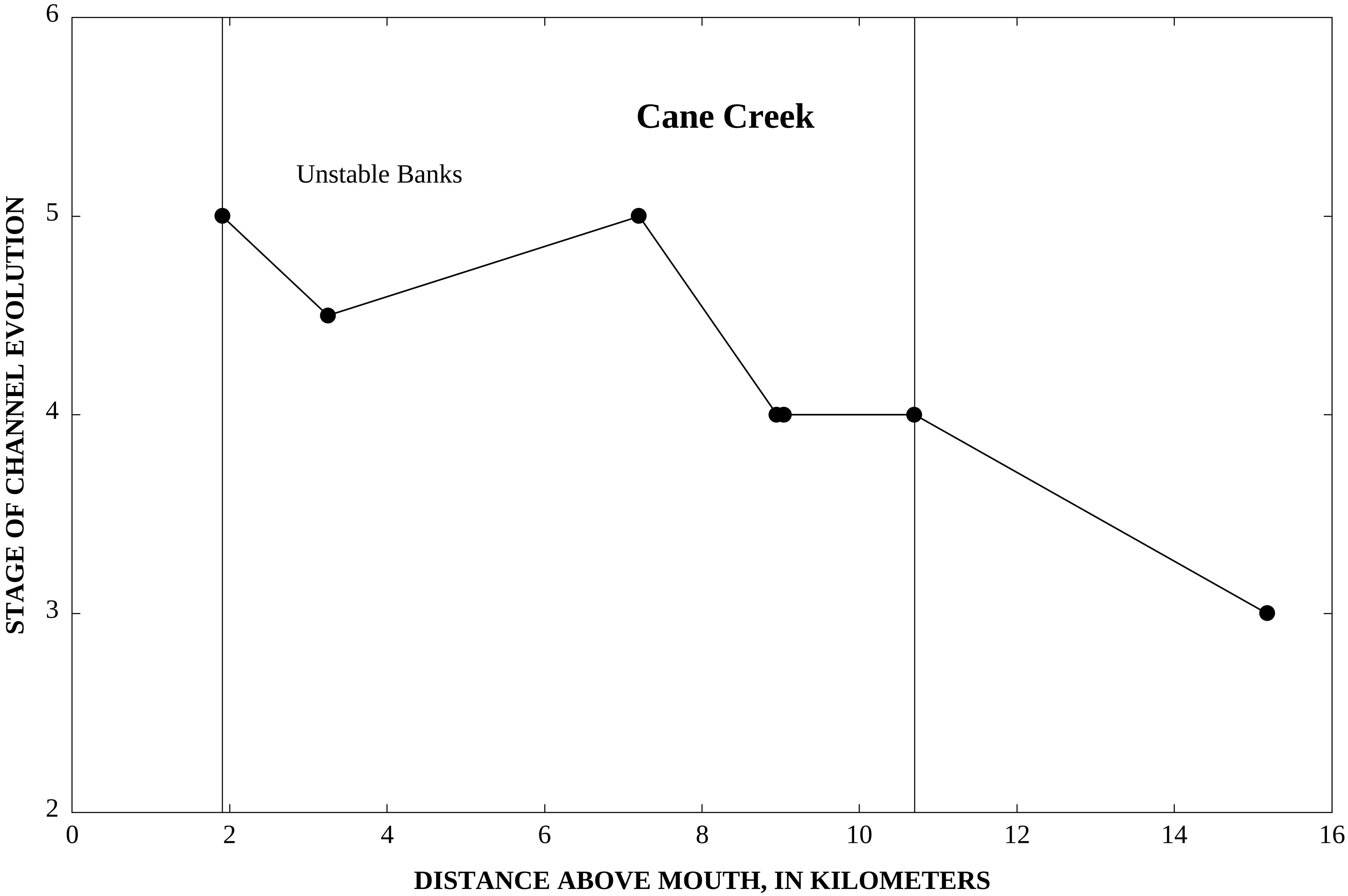
APPENDIX


Bear Creek
Unstable Banks
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
6
5
4
3
2
0
2
4
6
8
10
12
14

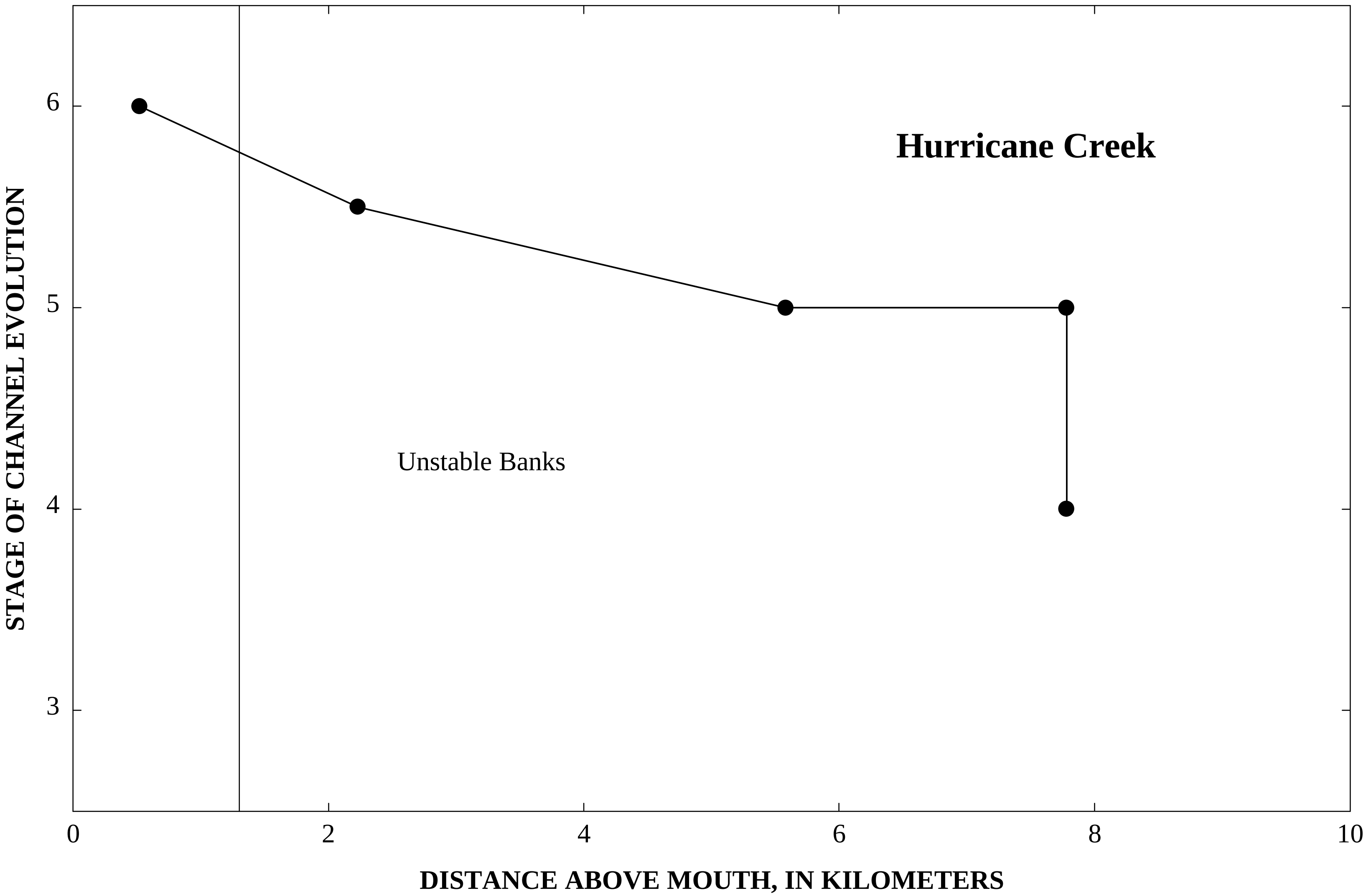

Big Creek
Unstable Banks
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
2
3
4
5
6
7
0
2
4
6
8
10
12
14
16
18

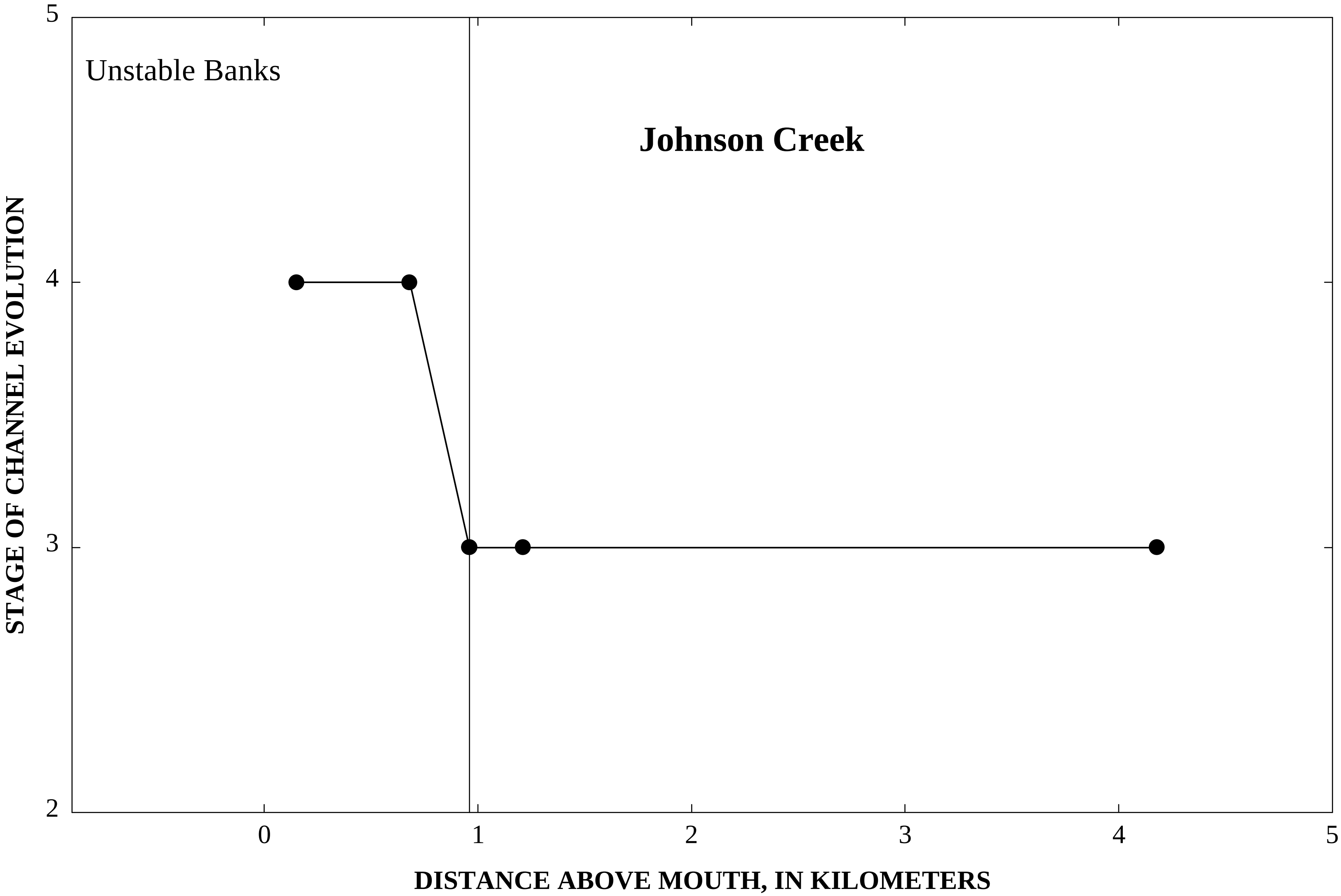

5
4
3
2
0
2
4
6
8
10
12
14
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
Unstable Banks
Buck Creek

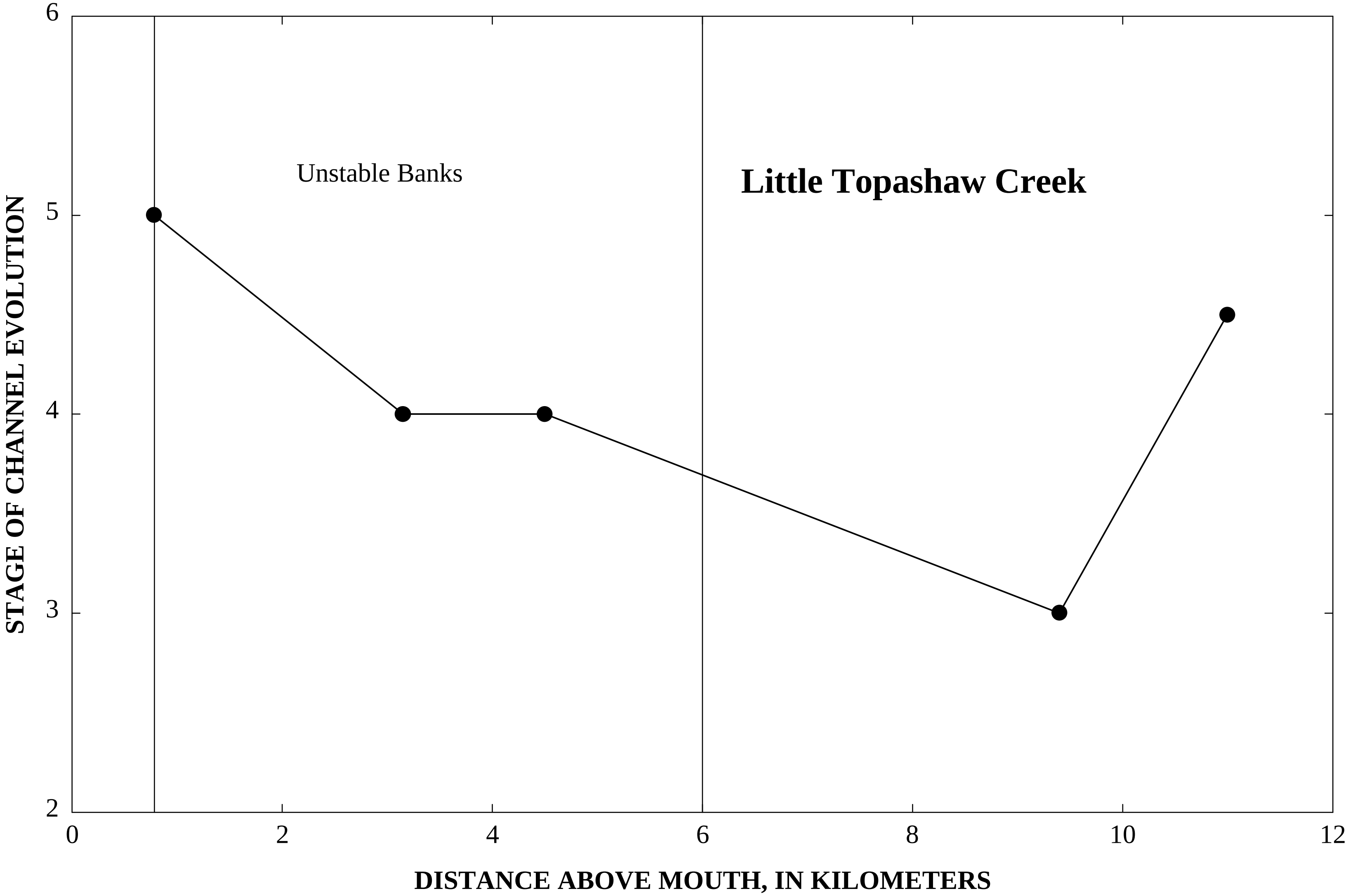

Bull Creek
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
1
2
3
4
5
6
0
1
2
3
4
5

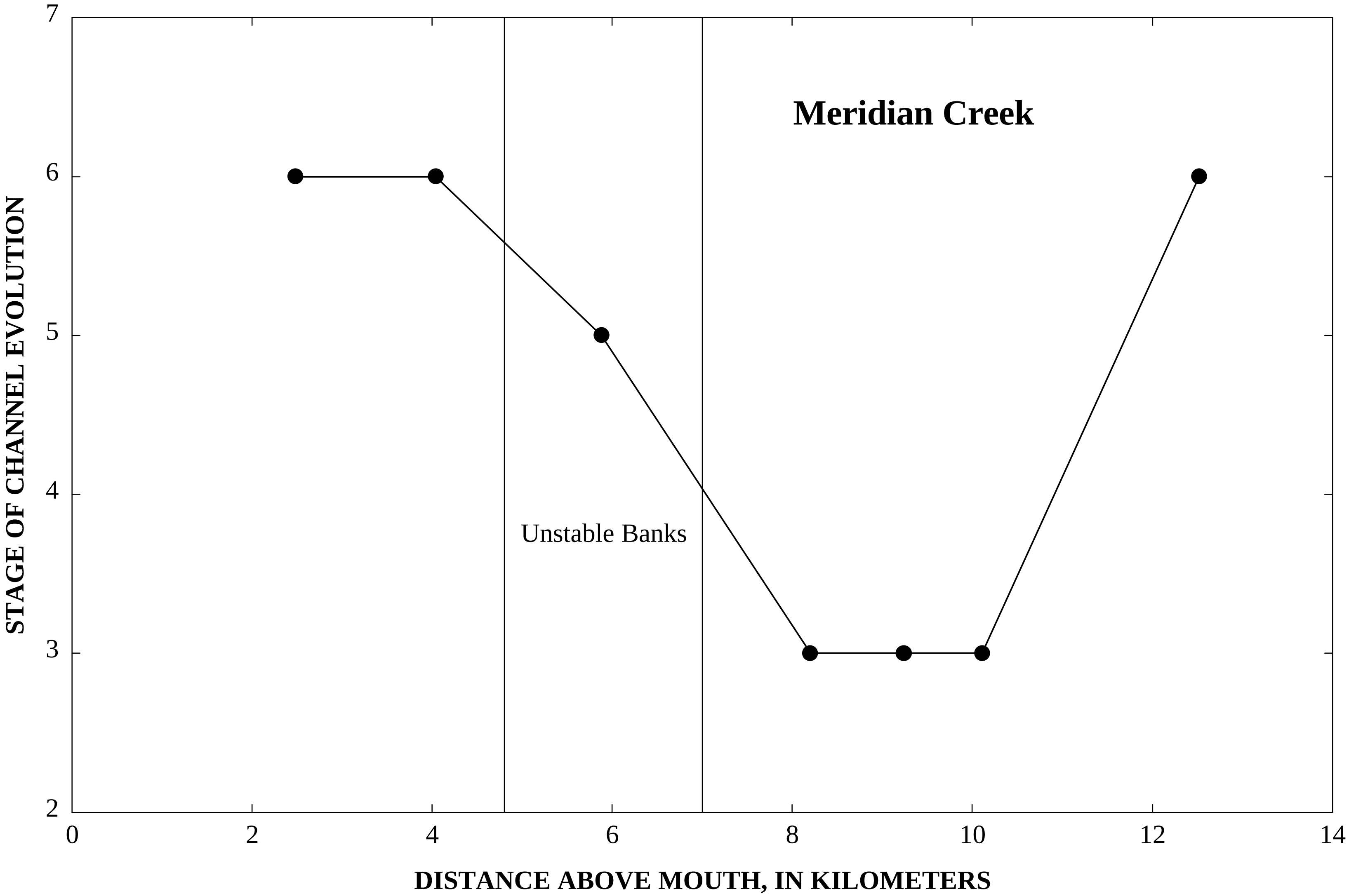


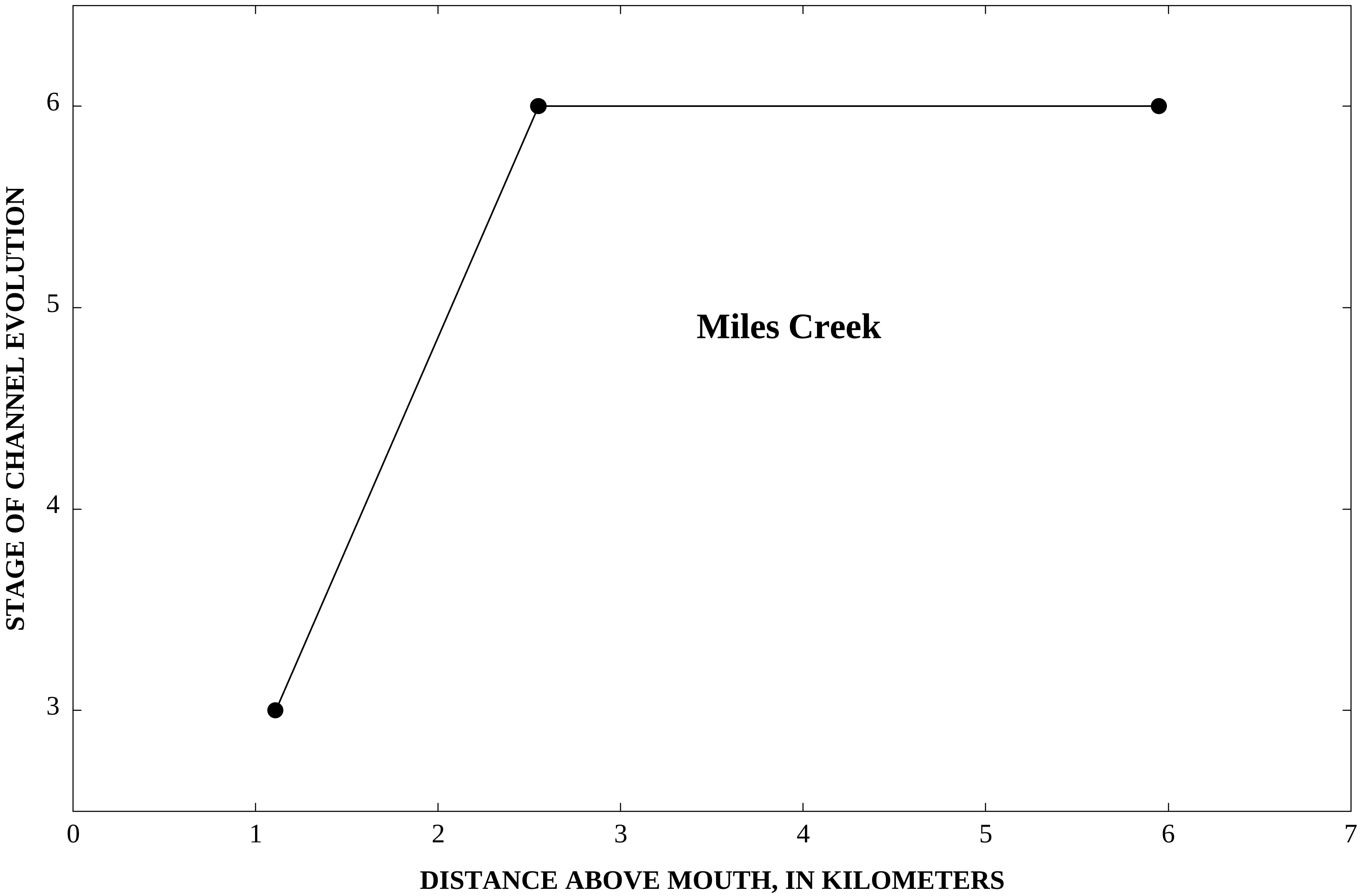
Cane Creek
Unstable Banks
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
2
3
4
5
6
0
2
4
6
8
10
12
14
16

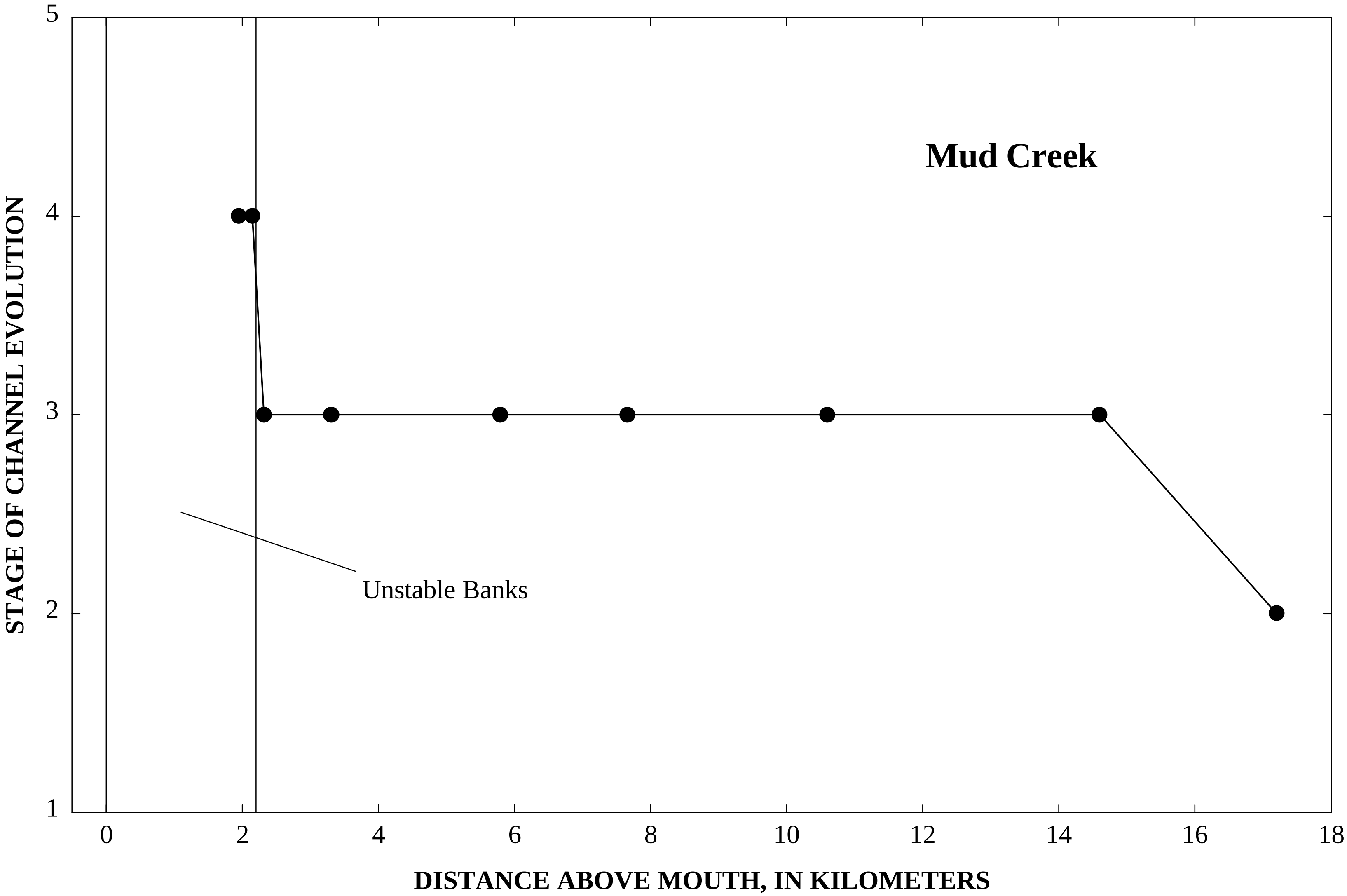

Hurricane Creek
Unstable Banks
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
3
4
5
6
0
2
4
6
8
10


Johnson Creek
Unstable Banks
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
2
3
4
5
0
1
2
3
4
5

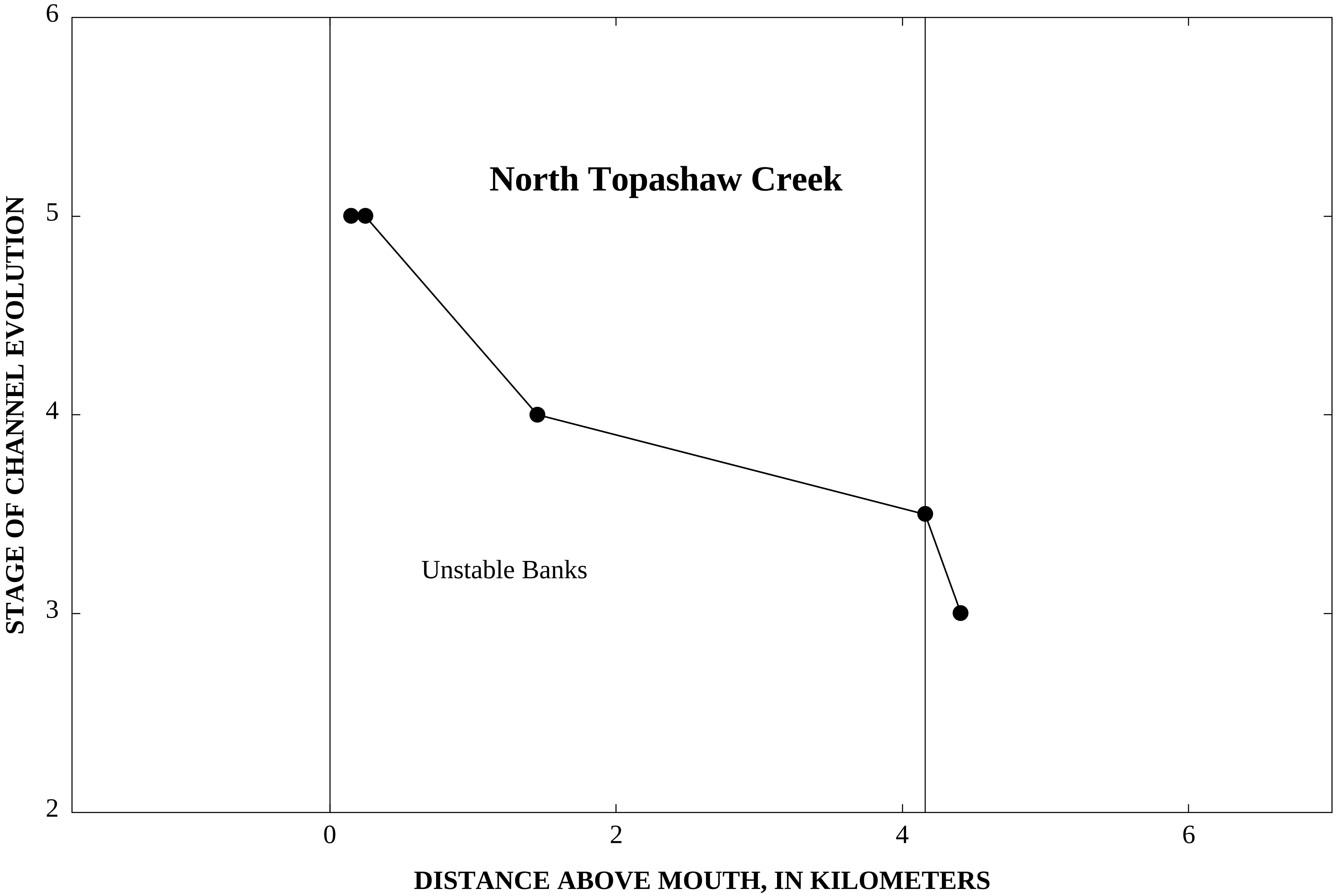

Little Topashaw Creek
Unstable Banks
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
2
3
4
5
6
0
2
4
6
8
10
12

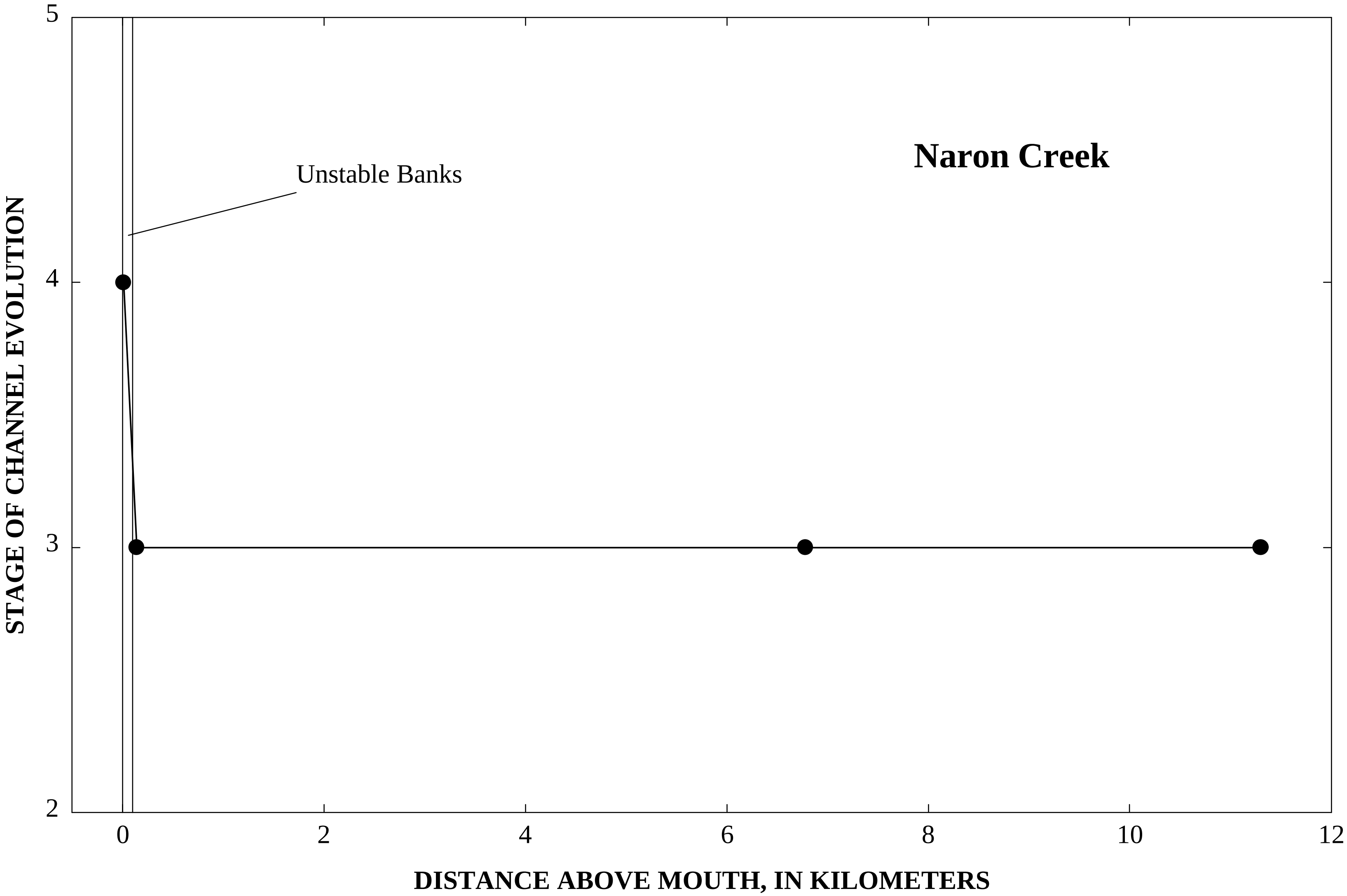

Meridian Creek
Unstable Banks
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
2
3
4
5
6
7
0
2
4
6
8
10
12
14


Miles Creek
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
3
4
5
6
0
1
2
3
4
5
6
7

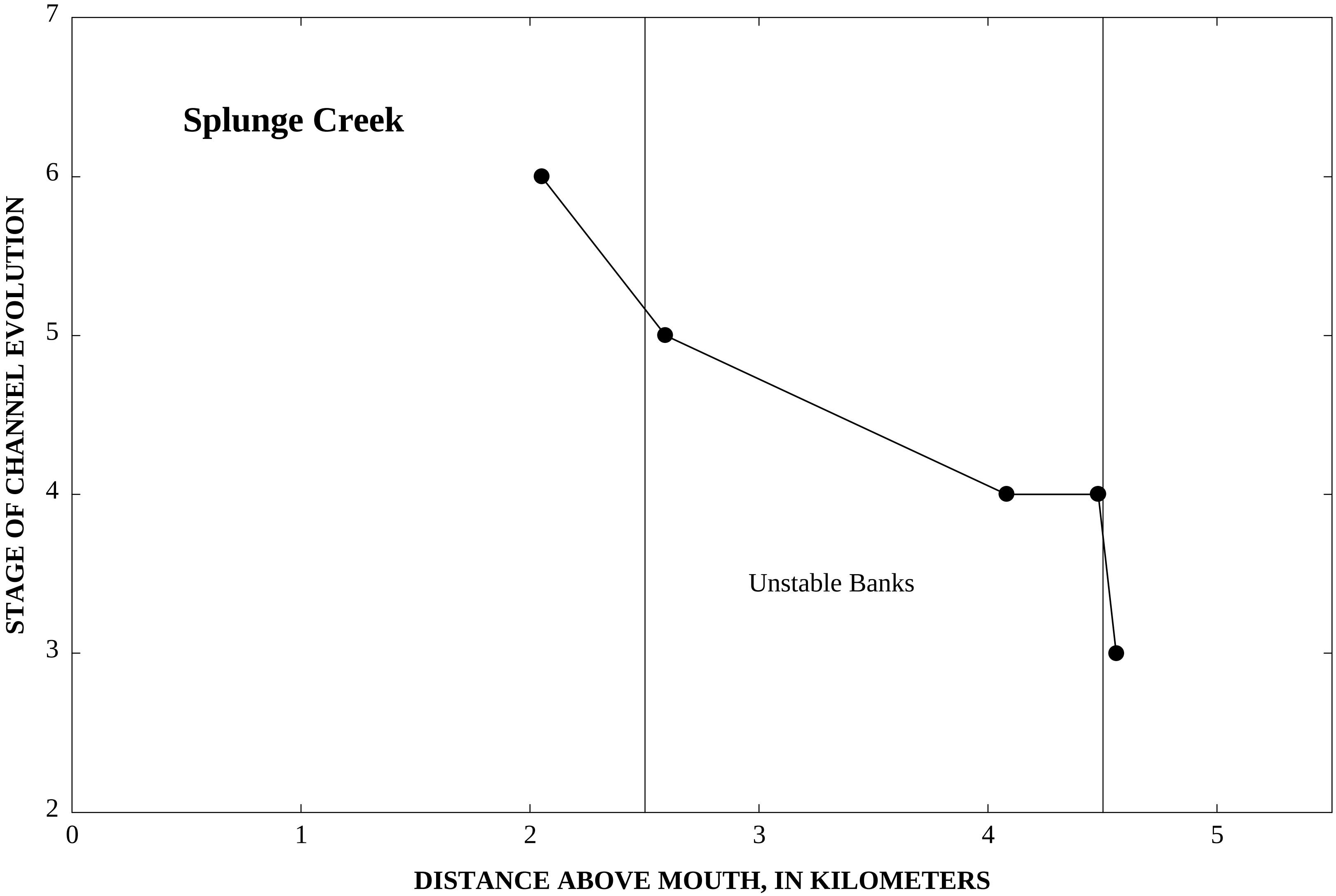


Mud Creek
Unstable Banks
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
1
2
3
4
5
0
2
4
6
8
10
12
14
16
18

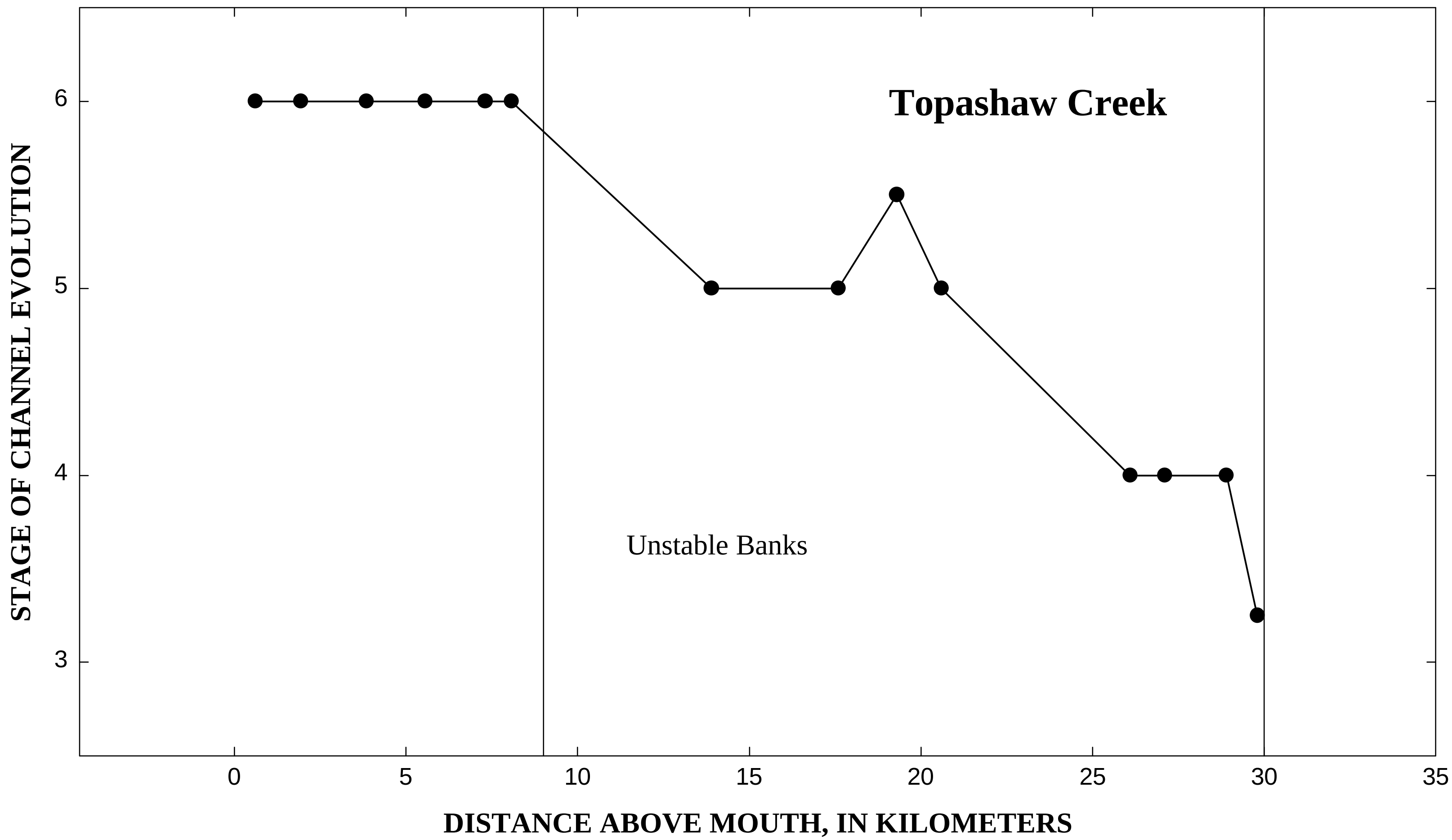

North Topashaw Creek
Unstable Banks
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
2
3
4
5
6
0
2
4
6



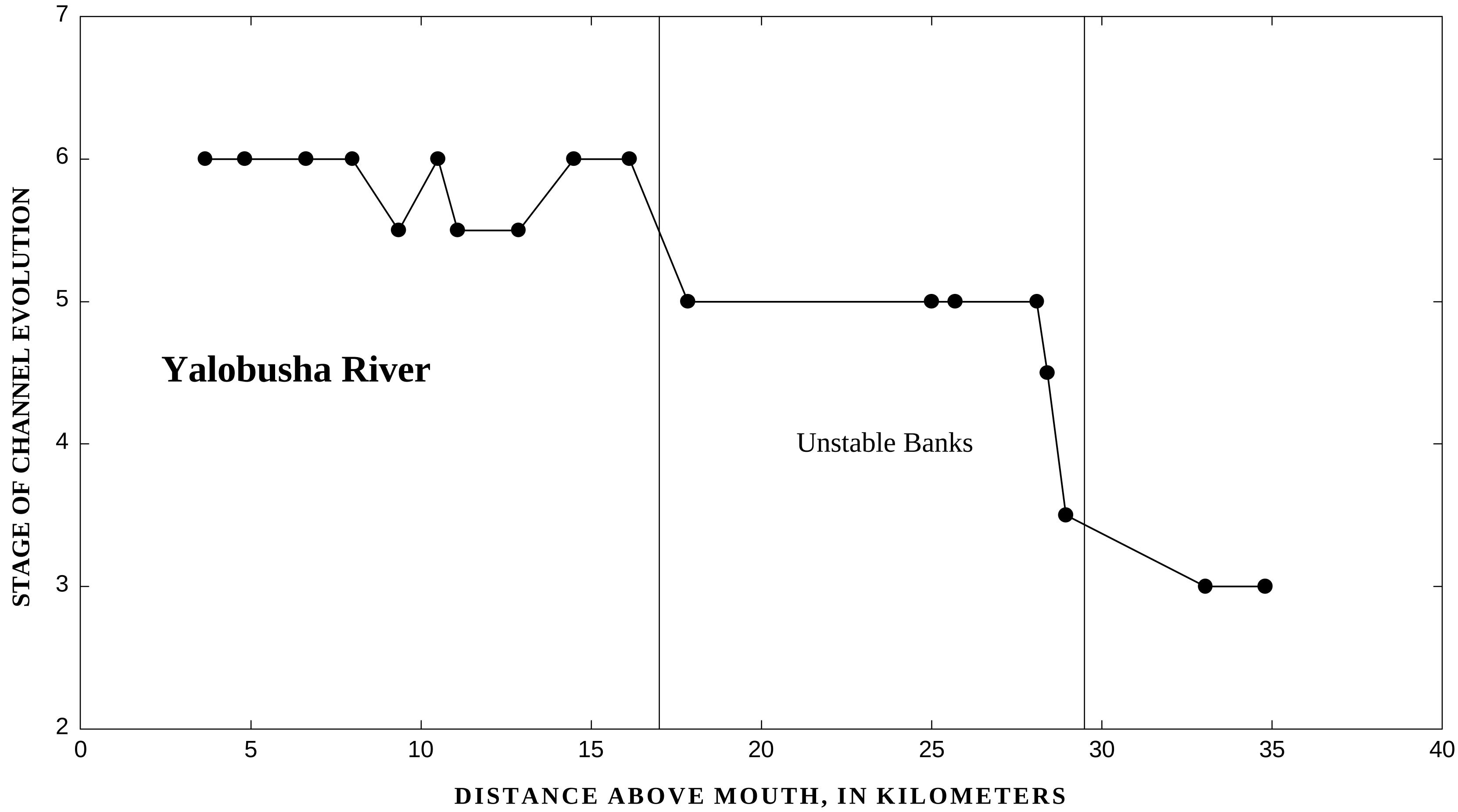
Naron Creek
Unstable Banks
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
2
3
4
5
0
2
4
6
8
10
12



Splunge Creek
Unstable Banks
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
2
3
4
5
6
7
0
1
2
3
4
5



Topashaw Creek
Unstable Banks
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
3
4
5
6
0
5
10
15
20
25
30
35


Yalobusha River
Unstable Banks
STAGE OF CHANNEL EVOLUTION
DISTANCE ABOVE MOUTH, IN KILOMETERS
2
3
4
5
6
7
0
5
10
15
20
25
30
35
40